SIEMENS

Interface description PROFINET IO Development Kits V4.7.0 10/2020

Programming and Operating Manual

10/2020

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Preface

Purpose of the manual

This user documentation describes the software functionality of the development kit for a PROFINET IO device.

Target group for the manual

This manual is intended for software and application developers who want to use the development kit for new products on various real-time platforms. Developers receive a software package with the complete source code of the IO stack, the documentation, an application example and an example platform porting.

This manual applies to ERTEC and standard Ethernet-based platforms.

Structure of the manual

This manual describes the PROFINET IO Device Development Kit and its usage It is structured as follows:

- Section 1: Introduction
- Section 2: Overview of PROFINET IO device software
- Section 3: Software creation for PROFINET IO devices
- Section 4: Interface description
- Appendices: Abbreviations / Glossary of terms, References

This manual includes the description of the PROFINET IO stack for the supported development kit at the time of release. We reserve the right to update the user documentation regarding new product releases.

Guide

The manual contains various navigation aids that allow you to find specific information more quickly:

- A table of contents is provided at the beginning of the manual.
- In the appendix you will find list of abbreviations and a glossary, which define important technical terms used in this manual.
- References to other documents are indicated by the document reference number enclosed in slashes ("/No./"). The complete title of the document can be obtained from the references in the appendix of the manual.

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In addition, you will find general information, current product information, FAQs and downloads that can be useful on the Internet (https://support.industry.siemens.com/cs/products/6es7195-3be00-0ya0).

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Table of contents

Introduction 1

PROFINET is an automation concept for implementing modular, distributed applications. PROFINET allows you to create automation solutions, which are familiar to you from PROFIBUS. PROFINET is implemented by the PROFINET standard for automation devices and by the engineering tool (STEP 7, TIA Portal). This means you have the same application view in engineering regardless of whether you are configuring PROFINET devices or PROFIBUS devices. As a result, programming of the user program is almost identical for PROFINET and PROFIBUS.

A software stack is offered for PROFINET. PROFINET IO device instances can be created on this basis. As a result, the user does not have to create the complete communication software.

The functionality includes:

- Cyclic and acyclic data exchange with one or more PROFINET IO controllers
- Sending and receiving of diagnostic and hardware interrupts, pull/plug interrupts
- Assignment of IP addresses and device names via Ethernet (DCP)

The stack is supplied in the source code and can be ported to any hardware and operating system platform. Necessary adaptations are encapsulated in defined interfaces to the hardware and operating system, thus enabling the stack to be ported as simply and cost-effectively as possible.

A good knowledge of PROFINET IO is required to implement the software stack.

1.1 Content and target audience of this interface description

This document is intended for developers of PROFINET IO devices.
It contains:

- Overview of the structure of the software stack
- Description of the PROFINET IO stack interface
- Description of the network and operating system connection of the PROFINET stack
- Description of the user example

This documentation does **not** include:

- Overview of PROFINET
- Description of the PROFINET protocol
- Detailed description of the PROFINET IO stack structure and processes

1.2 Example platforms

This documentation applies to the following platforms:

- Evaluation Kit ERTEC 200P, operating system eCos 3.0, with Evaluation Board EB 200P-2 or Minimal Design VAR2/VAR3

1.3 Other information

When porting the software to other platforms, we recommend that you do not modify the central components of the PROFINET IO stack (see section 2.2 (Page 17)). This will make it simpler to update to future versions.

The application examples were tested on the respective platforms (see section 1.2 (Page 13)).

Overview of PROFINET IO device software 2

2.1 Software architecture

The figures in the following subchapters show, how the PROFINET stack is embedded into different platform environments. The software of the PROFINET evaluation kits consists of the following components:

- PROFINET IO protocol software
- System adaptation and implementation of the application interface
- Real-time operating system
- Board support package (BSP) of the operating system
- Platform-specific adaptation layer
- Device application
- Trace system

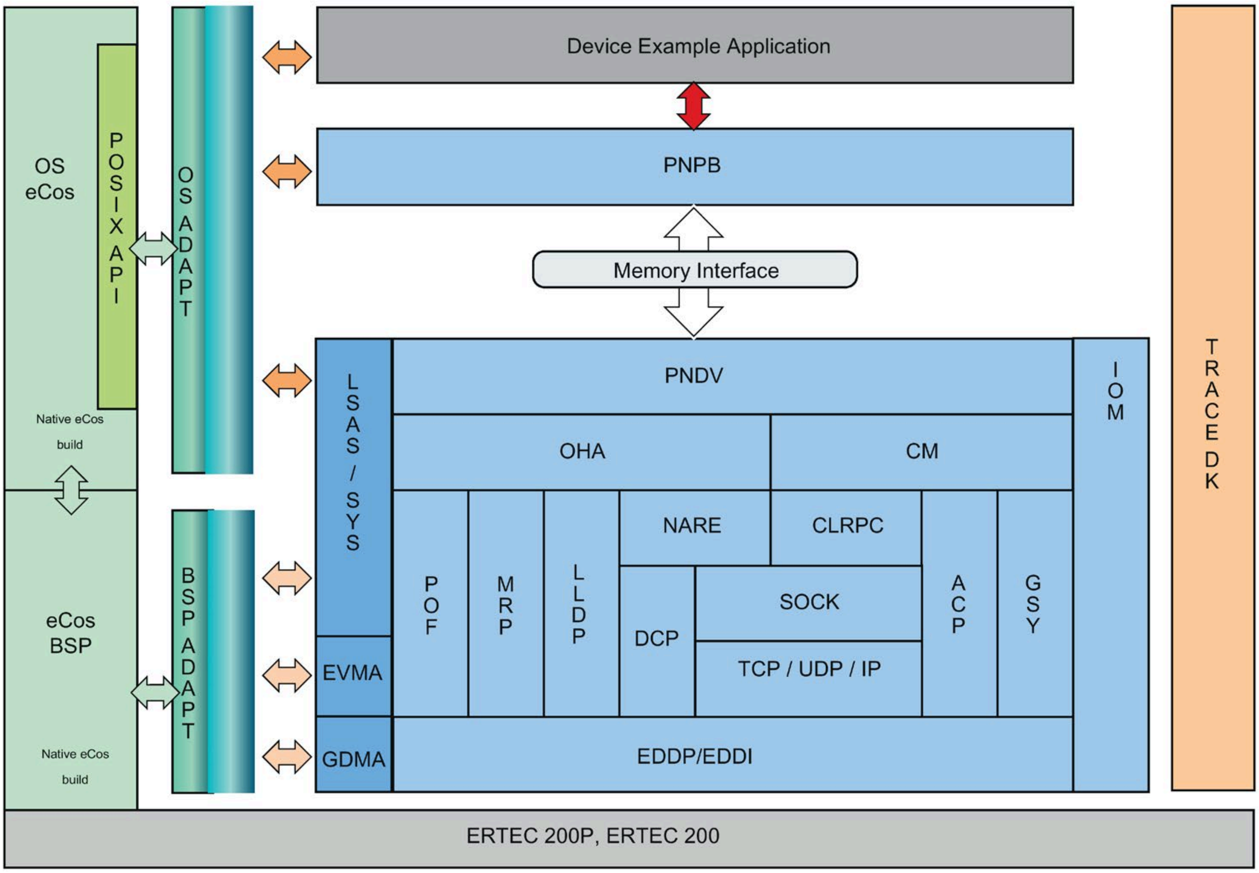
The PROFINET IO components are shown in blue and are provided by Siemens, as well as the trace system. The green components are generally supplied by the manufacturer of the operating system or microcontroller. Only the green to blue components must be adapted to the platform by the user (OS Adapt, BSP Adapt). The other components can normally be used without modification. Example code is included in the PROFINET IO software stack for the adaptation of the dark green components. It is suitable for the respective example platforms.

The other components can be used without modification.

Migrating the stack to other platforms is a common use case for the standard Ethernet development kit. However, the ERTEC development kits include a ready-to-use adaptation layer to eCos, so there is no need for the customer to make changes. If the customer’s hardware differs from the minimum HW design for the ERTEC that is provided by Siemens, then modifications may be necessary in the BSP of the operating system.

2.1.1 System environment and properties

2.1.1.1 Using the POSIX application interface



Red arrows	Application interface
Orange arrows	Operating system abstraction interface (OS Adapt)
Light orange arrows	Hardware abstraction interface (BSP Adapt)

Figure 2-1 POSIX OS adaption

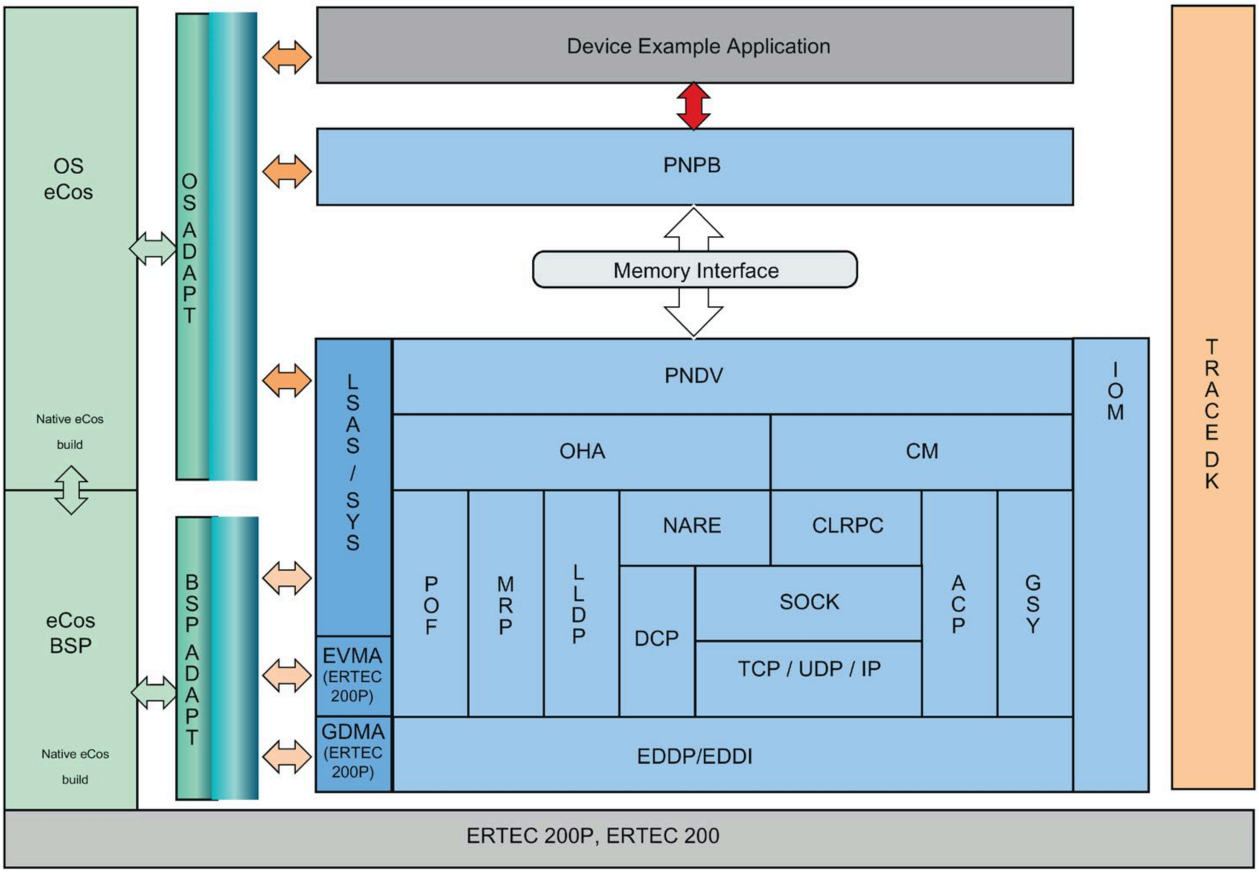
This platform has the following properties:

- Complete solution for PROFINET including Interniche IP stack
- SNMP Agent (MIB2, SNMP-MIB) contained in the stack
- Implemented for POSIX interface on eCos platform

See also

Porting to customer hardware with the same microcontroller and the same OS (Page 41)

2.1.1.2 Using the native eCos application interface



Red arrows	Application interface
Orange arrows	Operating system abstraction interface (OS Adapt)
Light orange arrow	Hardware abstraction interface (BSP Adapt)

Figure 2-2 Native eCos OS adaptation

This platform has the following properties:

- Complete solution for PROFINET including Interniche IP stack
- SNMP Agent (MIB2, SNMP-MIB) contained in the stack
- Implemented for native interface on eCos platform

See also

Porting to customer hardware with the same microcontroller and the same OS (Page 41)

2.2 Components of the PROFINET IO stack

The following subsection provides a brief overview of the components in the PROFINET IO stack. The components of the stack can basically be broken down into the following categories:

- **System-independent basic packages with a uniform interface structure**
  These include ACP, CM, CLRPC, DCP, EDD, GSY, POF, LLDP, MRP, NARE, OHA, TCP/IP Stack and SOCK. The basic packages merely provide a function library of sorts, which does not become an actual, executable system implementation until combined with the system integration.
- **System adaptation (SYS, LSAS, TSKMA) for all included software packages**
  This forms the interface between the system-independent basic packages and the operating system services, such as memory management, task management, interprocess communication, and time management. System adaptation also implements the software structure of the IO stack, i.e. which basic packages are executed in which tasks and which mechanisms the tasks use to communicate with each other.
- **OS abstraction layer (OS Adapt)**
  This forms a low-layer abstraction interface between the system adaptation and a specific operating system. As a result, when the software is ported to a different operating system, only the OS abstraction layer has to be adapted.
- **OS abstraction layer (BSP Adapt)**
  This forms a low-layer abstraction interface between the system adaptation and HW board-specific functionality.
- **GDMA, EVMA**
  These include the interface modules for interrupt handling and DMA (Direct Memory Access) handling.
- **PNDV**
  This includes the implementation of the generic parts of the device application.
- **PNPB**
  This forms the PROFINET IO device user interface for the customer application.

2.2.1 EDDP/EDDI (Ethernet Device Driver for ERTEC 200P/ERTEC 200)

The EDDP/EDDI provides mechanisms for:

- Independent sending and receiving of cyclic real-time message frames.
- Sending and receiving of acyclic real-time message frames.
- Sending and receiving of non-real-time message frames.

The EDDP/EDDI has a uniform LSA interface to higher-level clients (ACP, DCP, GSY, LLDP, MRP, etc.).

2.2.2 ACP (Acyclic Communication Protocol)

Processing of:

- Diagnostic alarms
- Alarms
- Return of submodule alarms
- Upload/retrieval alarms (parameter server)

The ACP generates the alarm message frames and monitors the correct functioning of the associated Ethernet protocol (alarm acknowledgments, timeout).

2.2.3 CM (Context Manager)

- Establishing and managing communication links between IO device and IO controller
  - Requests for establishment of communication links are sent by remote IO controllers to the context manager using "Connectionless Remote Procedure Calls" via UDP and CLRPC.
- Management of the actual configuration (inserted modules and submodules)
- Interface to the upper layer (PNDV)

2.2.4 CLRPC (Connectionless Remote Procedure Call)

- Implementation of the connectionless RPC protocol

2.2.5 DCP (Dynamic Configuration Protocol)

- Assignment of IP addresses and device names via Ethernet
- Reading readiness information, for example:
  - Which PROFINET devices are active on the network
  - Which PROFINET device has the following device name
  - Hello message for Fast StartUp signals readiness to establish a connection after power on

2.2.6 GSY (Generic Sync Module)

- Processing the synchronization message frames from the sync master
- Line length measurement
- Synchronization monitoring

2.2.7 LLDP (Link Layer Discovery Protocol)

- Protocol for the exchange of neighborhood information for topology discovery
- Cyclic sending of LLDP packets with the own station data (chassis ID, port ID, etc.)
- Receipt of LLDP packets from other stations and local storage
- Provides received data with the associated port ID
- Receive monitoring and notification to the user in the event of a change or loss of the LLDP data

2.2.8 MRP (Media Redundancy Protocol)

- Media redundancy for PROFINET devices
- An MRP client is supported.

2.2.9 NARE (Name Address Resolution)

- Allocation of IP parameters (IP address / subnet mask / default router) to an IO device
- IP address resolution with the help of ARP

2.2.10 OHA (Object Handler)

- Information functions for the application
- Generation of change messages for the application
- "Application" for DCP server and LLDP
- SNMP connection (agent) via SOCK

2.2.11 POF (Polymeric optical fiber)

- Support for optical transmission media POF and PCF (polymeric cladded fiber, not currently available for all platforms)

2.2.12 SOCK (socket interface)

- Internal adaptation interface for handling UDP-based services in the PROFINET stack

2.2.13 TCP/IP stack

- Implementation of TCP and UDP functionality (PROFINET only uses UDP)
- Based on Interniche TCP/IP stack
- Sending and receiving of raw Ethernet IP message frames
- Internal adaptation interface to PROFINET stack-internal SNMP MIB agents (MIB2, LLDP MIB)

2.2.14 System adaptation (SYS, LSAS, TSKMA)

- Shared implementation of the system adaptation of the individual basic packages
- Routing of operating system services for memory management, task and timer handling, and interprocess communication to the OS abstraction layer
- Implementation of tasks and communication between tasks

2.2.15 OS Abstraction Layer (OS Adapt)

- Operating system abstraction interface for PNIO
- PNIO components never directly access an operating system call; rather, access is via the OS abstraction layer only.
- Maps all requirements of the system adaptation onto simple operating system services, which are implemented almost 1:1 in a service call for most real-time operating systems.
  - This facilitates simple adaptability to another real-time operating system

2.2.16 BSP Adapt (Board support package adaptation)

- Forms a low-layer abstraction interface between the system adaptation and HW board-specific functionality
- For ERTEC 200P an SPI driver for SPI flash memories is included. It can be used for Adesto AT45DB321E 32Mbit flash and Winbond W25q64FV 64Mbit flash.

2.2.17 GDMA, EVMA (for ERTEC 200P only)

- EVMA: interface module for interrupt handling
- GDMA: interface module for DMA (Direct Memory Access) handling

2.2.18 PNDV

- Implementation of generic parts of the device application
- Starting and initializing the PROFINET stack
- Generation of tasks and communication channels within the PROFINET stack
- Communicates with higher-level layers via a stack-internal memory interface

2.2.19 PNPB

- Implementation of PROFINET IO device user interface for the customer application
- Communicates with the PNDV via an internal interface

2.3 Additional software components

2.3.1 Operating system

The real-time operating system is not part of the PROFINET IO software stack. It is generally procured from a third-party vendor. The supplied application example is customized for each example platform; see section Example platforms (Page 13).

2.3.2 Board support package (BSP)

The board support package (BSP) encapsulates the hardware-specific operating system calls for a specified platform. A platform-specific BSP is generally provided by the manufacturer of the operating system.

For the **ERTEC-based evaluation board** EB 200P, a BSP for the employed operating system is included in the evaluation kit product package. This can be used as an example template for adapting a BSP to a customer-specific platform.

For the **ERTEC-based development kits** eCos is used as an operating system. Like many other realtime OS, eCos also provides a POSIX interface, to make software porting easy.

The **ERTEC 200P** kit provides 2 different system adaptations:

- Adaptation to the native OS application interface
- Adaptation to the POSIX application interface

Note

The ERTEC 200P customer may decide which interface shall be used. Use either the native OS-API or the POSIX-API.

2.4 Application examples

Various application examples have been integrated into the development kit to optimally adapt PROFINET to a wide variety of requirements. They include examples of how to use the API and can be used as templates for your own implementation.

The following access mechanisms have been implemented in the PROFINET stack for IO data access:

- Standard Interface (SI): universally applicable, for simple handling of RT and IRT.
- Direct Buffer Access Interface (DBAI): offers performance advantages when there is a large number of modules/submodules and can be used for RT and IRT.

With respect to IO data access, the application examples included in the development kit are each based on one of the interfaces listed above. Access to acyclic services like PROFINET stack startup, connection establishment, reading and writing records or interrupt handling is identical for the interfaces listed above. Additional information on the interfaces and acyclic services is available in section Important constraints for integrating an application (Page 41).

When creating your own application, we recommend that you start with the supplied application examples. The following table provides points of reference for selecting the best suited application example.

Application	**Description**	**Properties**
App1_Standard	Universal example, based on the standard interface (SI).	• Recommended template for most applications • Simple and fast implementation • Used for RT and IRT (DK_SW only RT) • Independently manages multiple ARs • Module/submodule-oriented view from the application onto the IO data, which means it need not know about the ARs or IOCRs. • Data consistency is automatically guaranteed by means of buffered access
App2_DBAI	Direct Buffer Access Interface	• Performance advantages compared to SI (only) if a large number of modules/submodules is used • Used for RT and IRT (DK_SW only RT) • Example shared device is not implemented • Data consistency is automatically guaranteed by means of buffered access

Application	Description	Properties
App3_IsoApp	Isochronous application for IRT (not for DK_SW)	• Structure similar to "App1_Standard", which means the same access method for IO data and acyclic services • Employs IO modules that require IRT, which means it can only be used in IRT mode • Manages ISO record index 0x8030 for specifying T_Input, T_Output and cycle time • Triggers interrupts or hardware signals GPIO 5-7 at the time T_Input and T_Output
App4_XHIF	Application example, based on the XHIF interface	• Used for RT and IRT • Independently manages multiple ARs • Module/submodule-oriented view from the application onto the IO data, which means it need not know about the ARs or IOCRs. • Data consistency is automatically guaranteed by means of buffered access

2.4.1 General structure of the application examples

The general software architecture of the PNIO stack has already been introduced in section Software architecture (Page 14). Application examples have a largely identical structure.

The application is mainly comprised of the following components:

- **Main task (entry function "mainAppl()")**
  This task starts by initializing the PROFINET stack. Then the task waits in an endless loop for keypad input via the function "OsGetChar()". Typical commands can thus be executed from a terminal connected to the RS232 interface, for example, sending interrupts, pulling/plugging modules during operation.
- **IO_Cycle task**
  This task cyclically executes an IO data exchange between the PROFINET stack and the application. The cyclic trigger here is either an event derived from the ERTEC (the so-called "TRANS_END" event = point in time at which the current output data in the device is made available) or a fixed wait time.
  The "TRANS_END" event (not for DK_SW) signals the end of the transmission phase of cyclic data for IRT, which means all provider IOCRs have been sent and all consumer IOCRs have been received. However, it can also be used for RT, in which case it signals that all local provider IOCRs were sent. If a fixed waiting period is used as trigger instead, there is no synchronization between application cycle and bus cycle.
- **Event handler**
  The callback functions of the PROFINET stack are called here to inform the application about important events, such as the establishment and termination of a connection, the reading and writing of records, "TRANS_END", etc. The event handlers run in the context of the PROFINET IO stack.

The figure below shows the implemented task structure; it applies to all application examples. The large arrows indicate where the tasks are created and started.

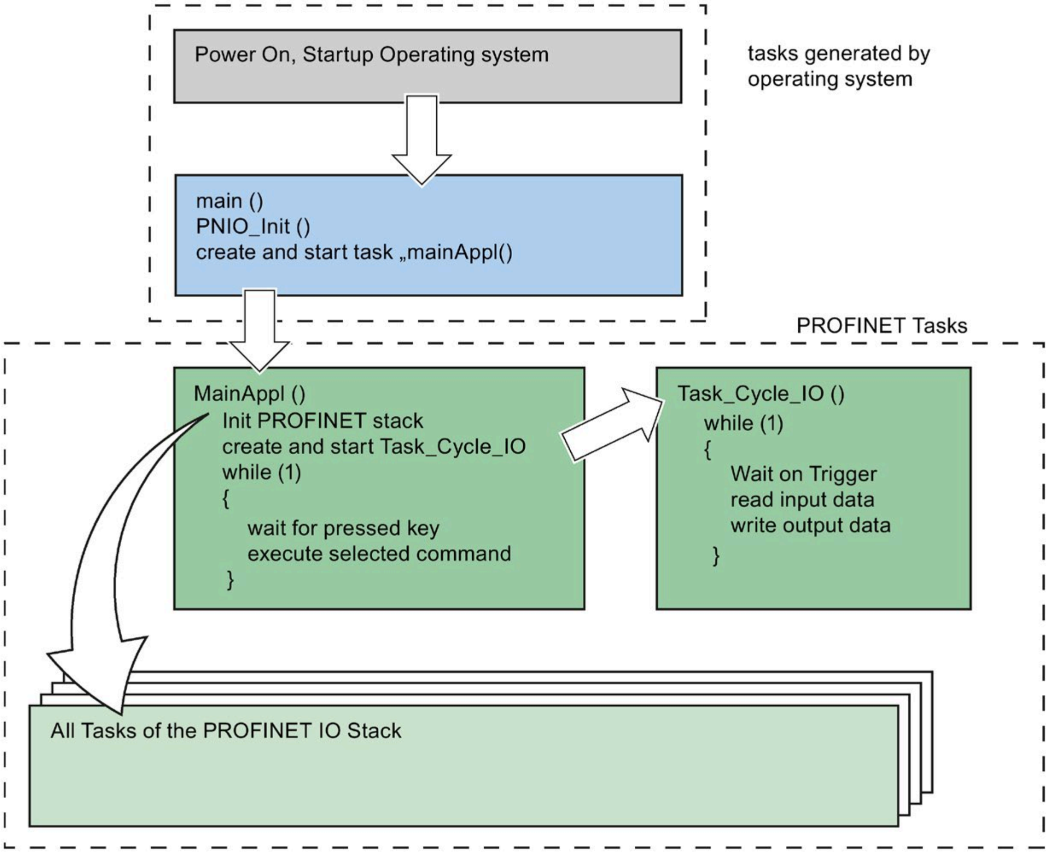


Figure 2-3 Tasks of the PROFINET IO application example

Directory structure of the source code for the application examples

All application examples are located under a common "(...)\pn_ioddevkits\src\application" directory. It contains a separate subdirectory for each application example. Functions and header files that are used by all application examples are located in the "\App_common" subdirectory.

A description of the directory structure of the complete PROFINET stack, including the application examples, can be found in section Directory structure of the PROFINET IO source code (Page 32).

The selection of the application example to be compiled is made in the "(...)\pn_ioddevkits\src\application\App_common\usrapp_cfg.h" header file by means of the following entry:

```
#define EXAMPL_DEV_CONFIG_VERSION 1 // the number 1..n specifies the selected example
```

You can therefore easily add your own application examples under a new number. This means you can copy and modify the delivered examples without changing the originals.

2.4.2 Isochronous applications with IRT, T_Input and T_Output evaluation

IRT communication can basically be performed with all IO modules. The standard modules used in the application example (ID = 30h, 31h in the example GSD file) can be configured for both RT and IRT mode.

Modules can also be defined in the GSD file that can only be configured for IRT mode (ID = 50h, 51h in the example GSD file). For these modules, an additional parameter startup record is transmitted from the IO controller to the device during connection establishment (IsochronousModeData record, index 8030H). It contains additional information about the IRT time constraints, such as T_IO_Input, T_IO_Output, T_IO_InputValid, and T_IO_OutputValid. The figure below from the PROFINET specification clarifies the relationships:

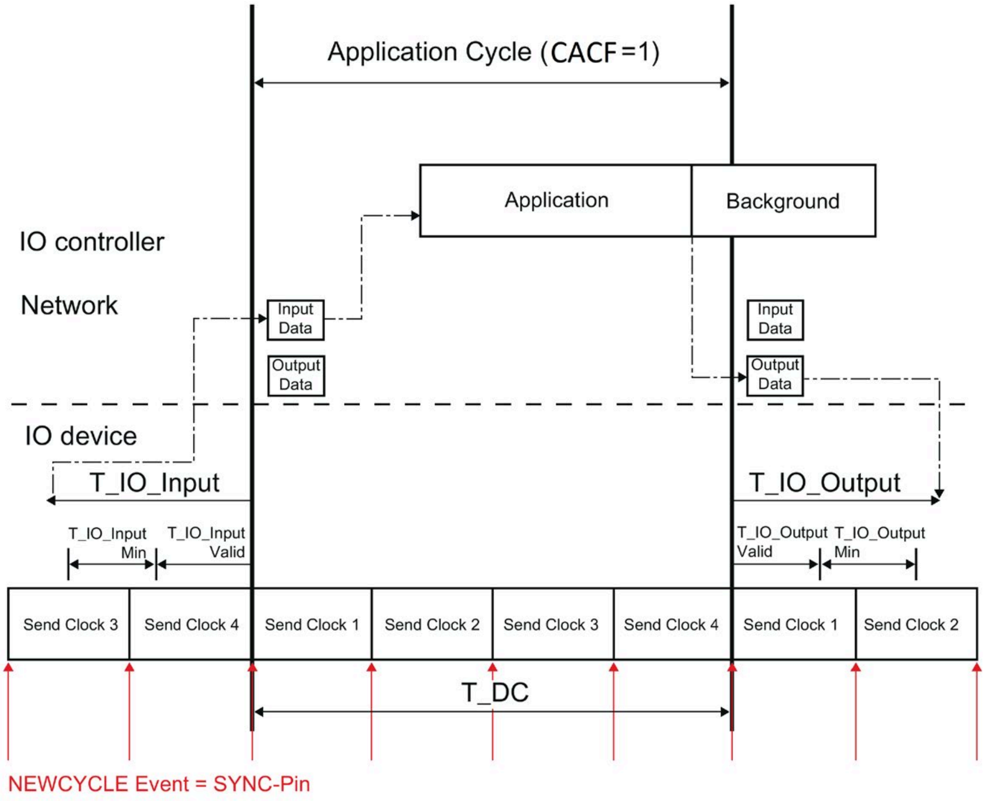


Figure 2-4 IO data exchange concept in isochronous applications

It is possible to precisely specify the times for the reading of inputs and the activation of outputs with this information and thus control highly dynamic processes.

The application examples evaluate this record and display the values listed above on the console.

Additionally, GPIOs 5 and 7 can be configured in such a way that each emits a short pulse at the time T_IO_Input or T_IO_Output. The sync signal edge arrives at the bus at the beginning of each send cycle, which means without taking into account a possible reduction ratio value.

The selection of the application example to be compiled for this is made in the "(...)\pn_ioddevkits\src\application\App_common\usrapp_cfg.h" header file by means of the following entry:

```
#define EXAMPL_DEV_CONFIG_VERSION 3 // the number 1..n specifies the selected example
```

Additional information on this topic is also available in the PROFINET specification /1a/ and /1b/.

2.4.3 App1: SI-based example for RT and IRT

Area of application

This is the standard application example which can be used for most applications. The SI can be used for RT and IRT (DK_SW only RT) and has a uniform user interface for both operating modes. The application need not be concerned with the structure of the IOCR in the data frame; this is undertaken by the PNIO stack. The management of multiple ARs ("Shared Device" function) is also independently performed by the stack. The application generally only has a view of the IO modules, independently of the AR. As a result, it is easy to implement an application for the SI.

Description of IO data access

IO data access occurs granularly at the submodule level by means of callback functions. The application initiates cyclic IO data exchange by calling "PNIO_initiate_data_read()" or "PNIO_initiate_data_write()". The PNIO stack then calls the callback function "PNIO_cbf_data_read()" for the output data coming from the IO controller of every single submodule; the callback function "PNIO_cbf_data_write()" is called for each submodule for the input data of the device. In it, the application must write or read the IO data for precisely one submodule. Here, the provider status of the output data from the IO controller and the provider/consumer status of the device input data are passed as transfer parameters or return values of the callback.

2.4.4 App2: DBAI-based example for RT and IRT

Area of application

This application example will offer possible performance advantages in comparison to the standard interface (SI), if a very large number of submodules is configured (e.g., with a proxy). The DBAI can be used for both RT and IRT (DK_SW only RT), and has a uniform user interface for both operating modes. During data access, the application operates on a single buffered image of the IOCR, where it directly accesses the IO data and the IOPS/IOCS provider/consumer status. This means the application establishes the IOCRs itself, but must for this reason know and manage their structure. The necessary information for this is passed when a connection is established to the device application in the Connect and the Ownership indication.

Description of IO data access

For each access to an IOCR, the application first calls the "PNIO_dbai_buf_lock" function. It thereby receives a pointer to a buffered and consistent IOCR. The application then makes direct read/write access to the submodule IO data contained in the IOCR and to the IOPS/IOCS (depending on the direction of data transfer: provider IOCR for input data, consumer IOCR for output data).

After processing, the buffer is released again by calling "PNIO_dbai_buf_unlock()". With a provider IOCR (which means input data on the device), the new IOCR image is now activated on the bus.

2.4.5 App3: SI-based example for IRT with a synchronized application

Area of application

This application is very similar to App1 “SI-based example for RT and IRT” but uses different IO-modules that can be used only in an IRT communication with synchronized application. That means, in the TIA project T-input and T-output are configured and during startup they are handed over to the user application with the record index 0x8030. See also section “Isochronous applications with IRT, T_Input and T_Output evaluation” (Page 25) for more information.

This example shows also, how to configure GPIOs as a trigger signal with a specified delay to the moment of NewCycle or execute a software code at that point in time. In that way, GPIOs can be used for triggering T-input and T-output. Configuring these signals or callback-functions can be activated in this example by console command ‘W’ and deactivated with ‘w’.

Description of IO data access

Data access itself works in the same way as App1 “SI-based example for RT and IRT”.

2.4.6 App4: XHIF example for communication with external host

Area of application

The application example is the same as App1_Standard, but it is running on the BeagleBoneBlack (BBB) board instead of the ERTEC 200P board. A proxy/stub software transfers the user interface from the ERTEC to the BBB, so that the same application interface functions are accessible on the BBB. Transferring the commands and function parameters between BBB and the ERTEC system is done with the XHIF interface that uses a memory range in the SDRAM for the transfer.

On the BBB an RT Linux distribution from Texas Instruments is running, based on Linux kernel 4.19.94.

For this example, the MinimalDesign ERTEC 200P_VAR3 board is necessary, but not the evaluation board EB200P. The MinimalDesign ERTEC 200P_VAR3 is a reference design, which contains MinimalDesign ERTEC 200P_VAR2, adapter board and BBB. The VAR2 and VAR3 boards are not purchasable but they are available as an EAGLE CAD project on the ERTEC 200P kit CD.

Find more information about this example in the file "(...)\doc\SW\Guideline_EvalKit_ERTEC200P_ V4.7.0.pdf" which is available on the CD "SIMATIC EK-ERTEC 200P PN IO V4.7.0”.

Description of IO data access

Data access from user application on BBB works in the same way as App1 “SI-based example for RT and IRT”.

2.5 Miscellaneous services

2.5.1 Dynamic reconfiguration

With dynamic reconfiguration a module or submodule can be added, removed or changed during a running application relation (AR). The IO data exchange of the not affected modules and submodules is not disturbed, because the AR does not break down when the configuration is changed. That means, dynamic reconfiguration provides a bump-free change of the configuration.

The concept of dynamic reconfiguration works in the following way: While one AR is running, a second AR with the new configuration is established, that will run in backup mode at first. Then a switchover from AR1 to AR2 is executed, so that afterwards AR1 will run in backup mode and AR2 in primary mode. At the end, the backup AR1 is deleted and only AR2 is running.

Dynamic reconfiguration (DR) can be used in non-redundant and redundant systems. The following figure shows as an example the concept of dynamic reconfiguration in a non-redundant environment.

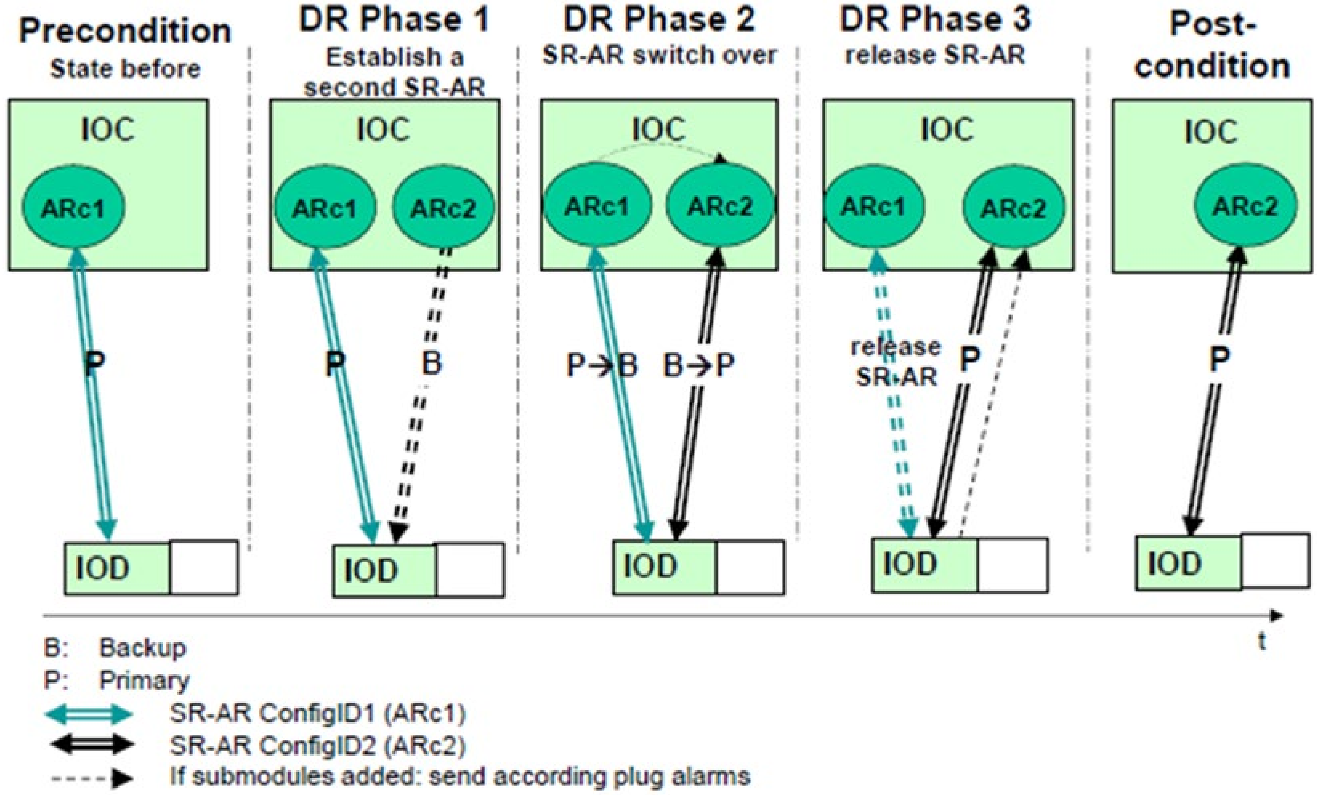


Figure 2-5 Concept of dynamic reconfiguration in a non redundant environment

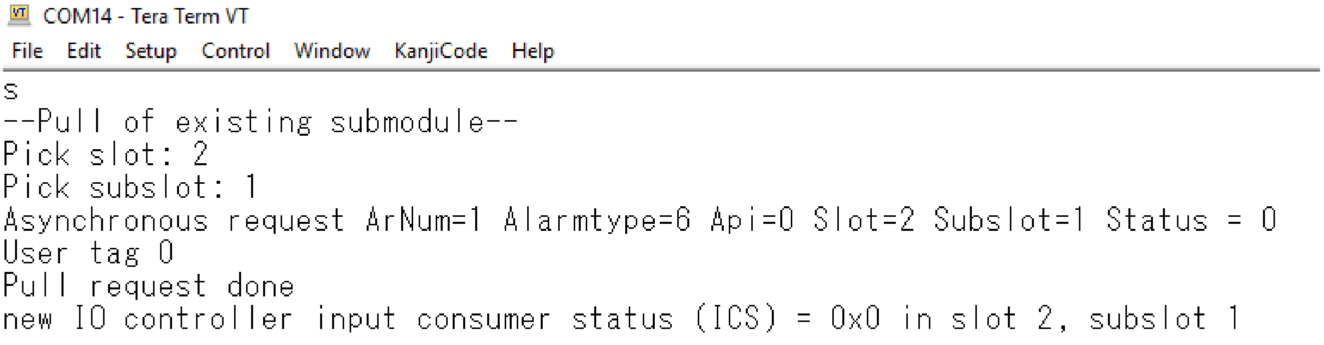
For more information about dynamic reconfiguration see the PROFINET specification /1a/ and /1b/.

In the software stack DR can be switched on or off in file

\pn_ioddevkits\src\application\App_common\iod_conf.h.

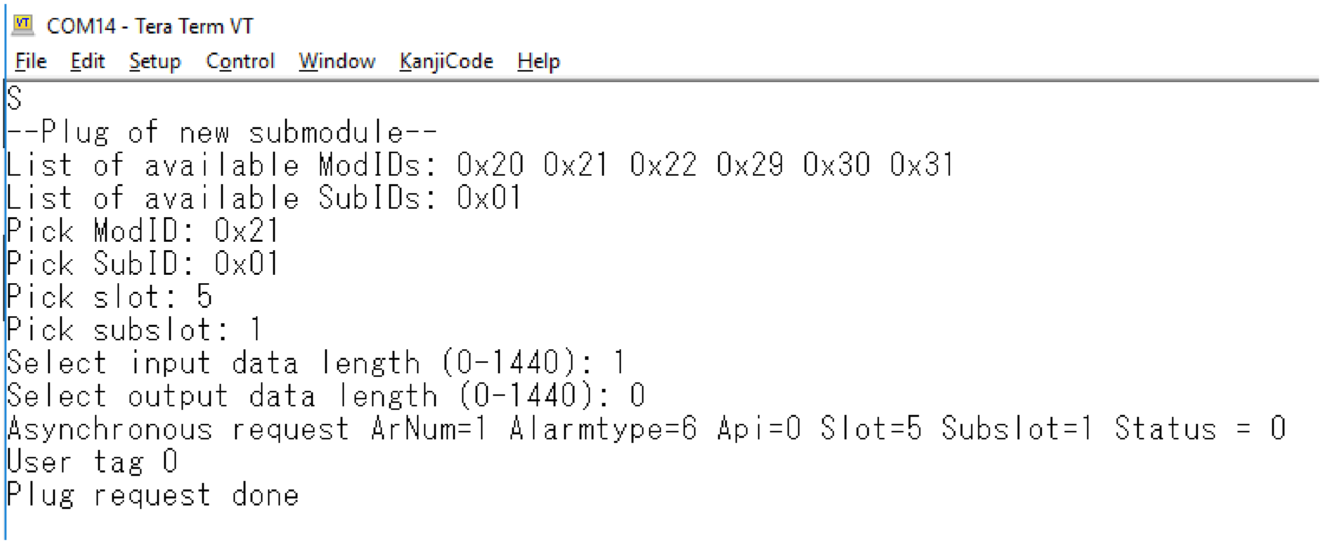
#define IOD_INCLUDE_DR 1 // 1: enabled 0: disabled

Pulling and plugging of IO modules is simulated by App1_Standard and App4_XHIF:



```
s
--Pull of existing submodule--
Pick slot: 2
Pick subslot: 1
Asynchronous request ArNum=1 Alarmtype=6 Api=0 Slot=2 Subslot=1 Status = 0
User tag 0
Pull request done
new IO controller input consumer status (ICS) = 0x0 in slot 2, subslot 1
```

Figure 2-6 Pull of IO module



```
S
--Plug of new submodule--
List of available ModIDs: 0x20 0x21 0x22 0x29 0x30 0x31
List of available SubIDs: 0x01
Pick ModID: 0x21
Pick SubID: 0x01
Pick slot: 5
Pick subslot: 1
Select input data length (0-1440): 1
Select output data length (0-1440): 0
Asynchronous request ArNum=1 Alarmtype=6 Api=0 Slot=5 Subslot=1 Status = 0
User tag 0
Plug request done
```

Figure 2-7 Plug of IO module

PCS7 CiR Configuration

- Documentation for PCS 7 V9.0 – Process automation with the SIMATIC PCS 7 CPU 410-5H controller (https://support.industry.siemens.com/cs/ww/en/view/96839331) chapter Configuration modifications in operation – CiR/H-CiR
- System Manual – SIMATIC PCS 7 Process Control System CPU 410 Process Automation (https://support.industry.siemens.com/cs/ww/en/view/109748473) chapter Plant changes during redundant operation - H-CiR

2.5.2 I&M5 data

While I&M0 data describe the properties of the PROFINET modules and submodules in a customer’s device, the I&M5 data describe similar information for the used PROFINET technology platform. The I&M5 data are handled completely inside the PROFINET stack, so it is “don’t care” for the application. Nevertheless, I&M5 support can be enabled or disabled at compile level.

In the software stack, I&M5 can be switched on or off in file

\pn_ioddevkits\src\application\App_common\iod_conf.h.

#define IOD_INCLUDE_IM5 1 // 1: enabled 0: disabled

2.5.3 Asset Management Record (AMR)

Asset management is an additional concept to get information about orderable units, which are not related to the PROFINET device- and address model. AMR can be read by sending an appropriate data read (read record (index = 0xF880) request to any slot or subslot of the device. The AMR is assigned to the complete device, but can be read out from every subslot on the device. It will return always the same AMR data record, which includes all asset management data of all affected submodules in one record. The structure of the asset management record is shown in the following table:

Table 2- 1 Structure of the Asset Management Record (AMR)

Structure	Element	SubElement	Example value
	Number of entries		2
AMR Block 1	IM Unique Identifier		Random number
	AM Location		Format 2 : Slot 1 subslot 1
	IM Annotation		“Insert Description here ”
	IM Order ID		“xxx -yyyy-zzzz”
	AM Software Revision		
	AM Hardware Revision		
	IM Serial Number		“123456789012 ”
	IM Software Revision		“Vx.y.z”
	AM Device Identification	Device SUB ID	0x0000
		Device ID	0x0000
		Vendor ID	0x0000
		Organization	0x0000
	AM Type Identification		0x0000
	IM Hardware Revision		0x0000
AMR Block 2	IM Unique Identifier		Random number
	AM Location		Format 2 : Slot 2 subslot 1
	IM Annotation		“Insert Description here ”
	IM Order ID		“xxx -yyyy-zzzz”
	AM Software Revision		
	AM Hardware Revision		
	IM Serial Number		“123456789012 ”
	IM Software Revision		“Vx.y.z”
	AM Device Identification	Device SUB ID	0x0000
		Device ID	0x0000
		Vendor ID	0x0000
		Organization	0x0000
	AM Type Identification		0x0000
	IM Hardware Revision		0x0000

The implementation of the AMR, i.e. the handling of the AMR record is done in the application, based on the service function PNIO_cbf_rec_read(). This service function is available in all application examples App1 to App4.

Software creation for PROFINET IO devices 3

The following subsections describe among other things the directory structure of the software, the interfaces, and the application examples. The modules in the subdirectories that are indicated in boldface can be adapted by the user. Those that are not indicated in boldface should only be changed in exceptional cases.

3.1 Directory structure of the PROFINET IO source code

The allocation of the source code to various subdirectories is geared toward the software structure of the IO stack for PNIO devices. The following table provides an overview.

Directories			Files	Description
{Install_Path}\pn_ioddevkits\src\source\appl_startup	\src\		main_xx.c	Entry point into the PROFINET IO software. Start the IO main task, mainAppl()
{Install_Path}\pn_ioddevkits\src\ application	\	**App1_Standard**	***.c**	**Standard application example for RT and IRT, uses the standard interface (SI) for IO data access**
	\	**App2_DBAI**	***.c, *.h**	**Direct buffer access (DBAI) application example for RT and IRT**
	\	**App3_IsoAppl**	***.c**	**Application example for synchronized IRT application (not DK_SW)**
	\	**App4_XHIF**	***.c**	**Application example for external host communication with XHIF between ERTEC200P_VAR3 board and external host**
	\	**App_Common**	***.c, *.h**	**Common modules, used by the various application examples.**
{Install_Path}\pn_run\src\acp	\src\	common\ inc\	*.h	Global and internal header files of the basic package
	\ src\	src\	*.c	Source code files of the basic package
{Install_Path}\pn_run\src\clrpc	\src\	common\ inc\	*.h	Global and internal header files of the basic package
	\src\	src\	*.c	Source code files of the basic package
{Install_Path}\pn_run\src\cm	\src\	common\ inc\	*.h	Global and internal header files of the basic package
	\src\	src\	*.c	Source code files of the basic package
{Install_Path}\pn_run\src\dcp	\src\	common\ inc\	*.h	Global and internal header files of the basic package
	\src\	core\	*.c	Source code files of the basic package
{Install_Path}\pn_run\src\eddp	\src\	common\ inc\	*.h	Global header files of the basic package
	\src\	xxx \	*.c	Source code and other internal subdirectories of the basic package, here summarized as \xxx\

{Install_Path}\pn_ioddevkits\src\source\eep	\	common\ inc\	*.h	Global and internal header files of the component
	\	src	*.c	Source code files of the eeprom handling
{Install_Path}\pn_ioddevkits\src\source\evma	\	common\ inc\	*.h	Global and internal header files of the component
	\	src	*.c	event manager
{Install_Path}\pn_ioddevkits\src\source\gdma	\	common\ inc\	*.h	Global header files of the component
	\	src	*.c	GDMA controller handling
{Install_Path}\pn_run\src\gsy	\src\	common\ inc\	*.h	Global and internal header files of the basic package
	\src\	core\	*.c	Source code files of the basic package
{Install_Path}\pn_ioddevkits\src\source\iom	\	common\ inc_com \	*.h	Global header files of the basic package
	\	src\	*.c	Source code files of the basic package
{Install_Path}\pn_run\src\lldp	\src\	common\ inc_com \	*.h	Global and internal header files of the basic
	\src\	src\	*.c	Source code files of the basic package
{Install_Path}\pn_ioddevkits\src\source\lsa	\	common\	*.h	Global LSA header of the basic packages
{Install_Path}\pn_ioddevkits\src\source\lsas	\	common\ inc\	*.h	Global header files of the basic package
	\	Adapt\	*.c	Source code for the system adaptation (configuration) of the individual basic packages
	\	Adapt_h\	*.h	Header files for the system adaptation (configuration) of the individual basic packages
	\	src\	*.c	Source code files of the basic package
{Install_Path} \pn_run\src\mrp	\src\	common\ inc\	*.h	Global and internal header files of the basic package
	\src\	src\	*.c	Source code files of the basic package
{Install_Path} \pn_run\src\nare	\src\	common\ inc_com \	*.h	Global and internal header files of the basic package
	\src\	src\	*.c	Source code files of the basic package
{Install_Path} \pn_run\src\oha	\src\	common\ inc\	*.h	Global and internal header files of the basic package
	\src\	src\	*.c	Source code files of the basic package
{Install_Path}\pn_ioddevkits\src\source\pcpnio_lsa	\	inc\	*.h	Adaptation of the trace interface for the (PNIO stack-internal) debugging
{Install_Path}\pn_ioddevkits\src\source\Platform	\	EB200p_ecos\ EB200p_posix_ecos\	*.h	Header files for the selection of the platform
{Install_Path}\pn_ioddevkits\src\source\pndv	\	common \ inc\	*.h	Global and internal header files of the basic package
	\	src	*.c	Source code files of the basic package
{Install_Path} \pn_run\src\pnio	\src\	common\ inc\	*.h	Global and internal header files
	\src\	src\	*.c	Version entry for software stack of the evaluation kit

{Install_Path} \pn_ioddevkits\src\source\ pnio_api_inc	\	common\	*.h	Header files for the PROFINET IO application programming interface
{Install_Path} \pn_ioddevkits\src\source\ pnpb	\	common\ inc\	*.h	Global and internal header files of the basic package
	\	src\	*.c	Source code files of the basic package
{Install_Path} \pn_run\src\pof	\src\	common\ inc_com \	*.h	Global and internal header files of the basic package
	\src\	dmi \	*.c, *.h	Source code and internal header files of the basic package
	\src\	edd \	*.c, *.h	Source code and internal header files of the basic package
	\src\	prm	*.c, *.h	Source code and internal header files of the basic package
	\src\	base	*.c	Source code of the basic package
{Install_Path} \pn_run\src\sock	\src\	common\ inc_com \	*.h	Global and internal header files of the basic package
	\src\	src\	*.c	Source code files of the basic package
{Install_Path} \pn_run\src\sys	\	cfg \	*.h	Configuration files for ERTEC, LSAS, PNDV, TRACE and more
	\	inc \	*.h	Header files for the basic package
	\	src	*.c	Source code files of the basic package
{Install_Path} \pn_ioddevkits\src\source \sysadapt1	\	**cfg \**	***.c, *.h**	**Modules to be adapted by the user: abstraction layer for OS and other platform specific functionality**
	\	inc \	*.h	Global header files for the system adaptation
	\	src \	*.c	Source code of the system adaptation that can generally be used without modification
{Install_Path} \pn_run\src\tcpip	\src\	common\ inc\	*.h	Global and internal header files of the basic package
	\src\	src	*.c	Source code files of the basic package
	\src_ iniche _core\	allports \	*.c, *.h	Source code / header files of the package
	\src_ iniche _core\	h\	*.h	Header files of the IP protocol
	\src_ iniche _core\	ip\	*.c, *.h	Source code / header files of the IP protocol
	\src_ iniche _core\	ipmc \	*.c, *.h	Source code / header files of the IPMC protocol
	\src_ iniche _core\	misclib\	*.c	Source code for the checksum calculation

	\src_iniche_core\	net\	*.c, *.h	Source code / header files lower layer adaptation
	\src_iniche_core\	snmp\	*.c, *.h	Source code / header files of the SNMP protocol
	\src_iniche_core\	snmpv1\	*.c	Source code of the SNMP protocol
	\src_iniche_core\	tcp\	*.c, *.h	Source code / header files of the TCP protocol
{Install_Path} \pn_ioddevkits\src\source\trace_dk	\	inc\	*.h	Storage of error messages in a circular buffer or output to the terminal program (connected via the RS232 interface) as a debugging aidHeader files for trace mechanism.
	\	\src	*.c,	Output of the alarms to the TeraTerm consoleSource codes for trace mechanism.
{Install_Path} \pn_ioddevkits\src\source\tskma	\	common\ inc\	*.h	Global header files of the task manager
	\	src\	*.c	Source code and internal header files of the task manager

3.2 Files for the application examples and system

3.2.1 Files for App1_STANDARD

Module	Content	Description
usriod_main.c	Main program for RT and IRT Example	Standard application example, main program for RT and IRT. Startup of the IO stack, main loop with functions initiated by keyboard for an RT application
iodapi_event.c	Signaling of events to the application	Event handlers for the application examples Standard RT and IRT. Contains functions that the IO stack calls when events occur such as the establishment/termination of connections, reception of alarms, etc., and thereby notifies the application of their occurrence. Users must implement these functions according to their requirements.

3.2.2 Files for App2_DBAI

Module	Content	Description
usriod_main_dbai.c	Main program for the DBA example	DBAI application example main program Start of the IO stack, main loop with functions initiated by keyboard for a DBA application (Direct Buffer Access)
usriod_main_dbai.h	Header file	Header file for usriod_main_dbai.c
iodapi_event_dbai.c	Signaling of events to the application	Event handler, only for the application example in usriod_main_dbai.c.

3.2.3 Files for App3_IsoApp

Module	Content	Description
usriod_main_isoapp.c	Main program for RT and IRT example	Standard application example, the main program for IRT Class 3 with isochronous IO submodules
iodapi_event_isoapp.c	Signaling of events to the application	Event handler for user examples standard IRT C3 with isochronous IO submodules. Activate the ERTEC comparators for handling T_Input and T_Output times according to the data in record index 0x8030. The required configurations of GPIOs (5, 7) are performed using the "PNIO_IsoActivateGpioObj()" function in this case. **Note**: Time-controlled interrupts can be enabled using "PNIO_IsoActivateIsrObj()". You can find an example for this in "usrio_main_isoapp.c", "W" or "w" key on the console.

3.2.4 Files for App4_XHIF

Module	Content	Description
usriod_main_xhif.c	Main program for XHIF example	Startup of the IO stack, startup of the XHIF stub
iodapi_event_xhif.c	Signaling of events to the application	Event handlers for App4_XHIF

3.2.5 Files for App_common

Table 3- 1 Files for the application example

Module	Content	Description
iod_cfg.h	Header file	Defines for the configuration of the device
iodapi_event.h	Header file	Header file for iodapi_event.c, may be adopted unchanged.

Module	Content	Description
iodapi_log.c	Logging of debug and error messages	Central signaling of errors and notes to the application, logging for debug purposes or initiation of error handling routines. The functions are called by the stack and must be implemented by users according to their requirements. Empty functions can also be implemented.
iodapi_rema.c	Retentive data	Transfer of retentive data (PDEV records) from the PNIO stack to the application for the purpose of storing them in non-volatile memory.
Perform_measure.c	Measuring the processor load	Optional performance measurement in the Idle Task (only intended for user example, not for a real device).
Perform_measure.h	Measuring the processor load	Header file for perform_measure.c
PnUsr_Api.c	Subroutines	Subroutines for the user example. The functions contained can be used as a function library in the customer application, if needed.
PnUsr_Api.h	Subroutines	Header file for PnUsr_Api.c
PnUsr_xhif.c	Subroutines	Implementation of the PNIO user API stub
PnUsr_xhif.h	Subroutines	Header file for PnUsr_xhif.c
Tcp_flash_fw.c	FW download via TCP	Main program for TCP-based services for transferring and flashing a new firmware.
TCP_IF.c	FW download via TCP	TCP-based services for the transfer of new firmware.
Tcp_IF.h	FW download via TCP	Header file for tcp_if.c
usrapp_cfg.h	Selection of a user example	A define is used to select the corresponding user example (RT, IRT Class 3, DBA Interface).
usriod_cfg.h	Configuration of the example	Defines for the configuration of the device
usriod_diag.c	Application program for diagnostics	Example for the handling of standard channel diagnostics including diagnostic alarm.
usriod_diag.h	Header file	Header file for usriod_diag.c, contains data structure definitions for the standard channel diagnostics, among other things
usriod_im_func.c	optional I&M handling in application	Template for handling the I&M functions in application. This is optional, because the default setting is that I&M handling is included completely inside the PN-stack and **we recommend using the default setting here**.
usriod_im_func.h	optional I&M handling in application	Header file for usriod_im_func.c
usriod_PE.c	PROFIenergy	Application example for the handling of a PROFIenergy record
usriod_PE.h	PROFIenergy	Header file for usriod_PE.c
usriod_AMR.c	AMR	Application example for then handling of Asset management record
Usriod_AMR.h	AMR	Header file for usriod_AMR.c
usriod_utils.c	Utilities	Utilities to measure the system load for debugging purposes
usriod_utils.h	Header file	Header file for usriod_utils.c

3.2.6 Files for App4_XHIF_Host (BBB)

Module	Content	Description
iod_cfg.h	Header file	Defines for the configuration of the device
Iodapi_event.c	Signaling of events to the application	Handling of PNIO callbacks
nv_data.c	Nv data storage	Non-volatile storage if data are stored in Host
Nv_data.h	Header file	Header for non-volatile storage

Module	Content	Description
Pnio_types.h	Header file	Definition of types
Pnpb_gpio_lib.c	PNPB LIB Core	Handling of GPIO pins controlling XHIF interface
Pnpb_gpio_lib.h	Header file	Header for Pnpb_gpio_lib.c
Pnpb_lib_acyc.c	PNPB LIB Core	Handling of acyclic messages through XHIF interface
Pnpb_lib_acyc.h	Header file	Header for Pnpb_lib_acyc.h
Pnpb_lib_int.c	PNPB LIB Core	Handling of cyclic messages through XHIF interface
Pnpb_lib_int.h	Header file	Header for Pnpb_lib_int.h
Pnpb_lib_main.c	PNPB LIB Core	Intialization, configuration and startup of memory Interface
Pnpb_lib_mem_int.c	PNPB LIB Core	Lower function for XHIF memory interface
Pnpb_lib_mem_int.h	Header file	Header for Pnpb_lib_mem_int.h
Pnpb_lib.h	Header file	Internal defines for pnpb lib core
Usriod_AMR.c	AMR	Application example for the handling of Asset management record
Usriod_AMR.h	AMR	Header file for usriod_AMR.c
Usriod_im_func.c	Optional I&M handling in application	Template for handling the I&M functions in application. This is optional, because the default setting is that I&M handling is included completely inside the PN-stack and **we recommend using the default setting here**.
Usriod_im_func.h	Optional I&M handling in application	Header file for usriod_im_func.c
Usriod_main.c	Main program for RT, IRT Example with XHIF Interface	Startup of the IO stack, startup of the XHIF interface and main application loop
Usriod_PE.c	PROFIenergy	Application example for the handling of a PROFIenergy record
Usriod_PE.h	PROFIenergy	Header file for usriod_PE.c

3.2.7 Application interface

The header files that define the application interface are stored in the "(...)\pn_ioddevkits\src\source\pnio_api_inc\common" subdirectory. **These files must not be changed.**

Table 3- 2 Header files for the application interface

Module	Content	Description
pniousrd.h	Macros and definitions	Contains global structures and definitions for the PROFINET IO application programming interface.
pniobase.h	Macros and definitions	Contains data types, constants and function declarations for the IO controller functionality of the IO application programming interface.
pnioerrx.h	Macros and definitions	Contains the error codes.
pnio_trace.h	Macros and definitions	Trace interface (redirection to the LSA trace).
iodapi_rema.h	Macros and definitions	Contains data types and constants of the REMA interface.

3.2.8 Operating system interface modules to be adapted

Table 3- 3 Files for the operating system abstraction interface in "(...)\pn_ioddevkits\src\source\sysadapt1\cfg"

Module	Content	Description
xxx_os.c	OS services	Abstraction interface for operating system service calls, where xxx stands for the platform (for example, eCos). The mapping of PNIO calls to platform-dependent operating system functions occurs here.
os_cfg.h	OS configuration	System configurations for PNIO: Definition of system resources for PNIO (e.g. Mutex).
os_taskprio.h	OS configuration	System configurations for PNIO: Setting of task priorities
compiler.h	Compiler-specific definitions	Definition of compiler-specific settings
compiler_stdlibs.h	Integration of standard header files	Definition of standard header files to be included

For the ERTEC 200P an additional POSIX interface is included, it can be used optionally instead of the interface of the operating system. In the POSIX interface the different features like message handling, thread handling, memory allocation handling etc. are divided up into different smaller software modules, so this is a little different from native implementation. The following table describes the POSIX adaptation modules:

Table 3- 4 Files for the optional POSIX operating system abstraction interface in "(...)\pn_ioddevkits\src\source\sysadapt1\cfg"

Module	Content	Description
posix_dat.c	Internal data interface	Internal data interface of POSIX layer
posix_memory.c	Memory adaptation	Implementation of OsAlloc- and OsFree functions for POSIX
posix_os.c	OS interface startup	Implementation of OsInit() for POSIX
posix_print.c	Message print- and console input functions	Implementation of print-related functions like PNIO_printf, PNIO_sprintf ..., also console input functions like OsGetChar(), OsKeyScan32(), ...
posix_queue.c	Message queues	Implementation of OS message handling for POSIX adaptation
posix_sync.c	Synchronization mechanisms	Implementation of semaphore- and mutex-handling for POSIX adaptation like OsEnter, OsExit, OsAllocSemB, OsFreeSemB,...
posix_thread.c	Threads	Thread handling for POSIX adaptation like OsCreateThread, OsStartThread,..
posix_timer.c	Timer	Timer handling for POSIX adaptation like OsAllocTimer, OsStartTimer, ...
posix_utilis.c	Miscellaneous data handling	String handling, copy and compare memory, data conversion big/little endian, ASCII-integer conversion, ... for POSIX adaptation

3.2.9 Modules of the BSP interface

Table 3- 5 Example files for adaptation to the board support package in "(...)\pn_ioddevkits\src\source\sysadapt1\cfg"

Module	Content	Description
xx_bspadapt.c	BSP adaptation	Interface from the IO stack to the platform
xx_ledadapt.c	Flash LED	User-specific implementation of a flash LED that can be started from the engineering system via DCP services.

3.2.10 Storage of retentive data

Table 3- 6 Files for the adaptation to retentive data in "(...)\pn_ioddevkits\src\source\sysadapt1\cfg"

Module	Content	Description
xx_flash.c	Read/write NOR flash	Interface with basic functions for writing, reading and erasing of the flash memory. The functions are only used in the example application and system adaptation and not in the stack itself.
xx_fw_update.c	Firmware update via TCP/IP	Functions for the firmware update via TCP/IP (for ERTEC-based kits). These are not used in the DK_SW, because platform manufacturers usually provide a solution themselves.
xx_nv_data.c	Storage of retentive data	Interface for structuring and storing non-volatile data such as device name, IP suite, REMA data. The basic functions in xx_flash.c are used to store the data itself.
xx_flash.h	Storage of retentive data	Header files with function declarations for handling of the flash. Changes are usually not necessary.
xx_bsp_spi_flash.c	Read/write SPI flash	Interface with basic functions for writing, reading and erasing of the SPI flash memory (specified Adesto and Winbond flashes, for more information see the document "(...)\doc\SW\Guideline_EvalKit_ERTEC200P_V4.7.0.pdf" which is available on the software package "SIMATIC EK-ERTEC 200P PN IO V4.7.0"). The functions are only used in the example application and system adaptation and not in the stack itself.
xx_bsp_spi.c	Basic SPI functions	Basic SPI functions, to handle the SPI flash memory (see above)

3.2.11 Files for system adaptation

Table 3- 7 Other files for system adaptation in pn_ioddevkits\src\source\sysadapt1\cfg

Module	Content	Description
hamaport.c	GPIO settings	Functions for configuring the GPIOs. Changes are usually not necessary.
xx_os_debug.c	Optional tools	Advanced information about the used resources of the operating system (tasks, memory, etc.). Can only be implemented for the eCos platform. The functions are optional and are only used in the example application, not in the stack itself.
Os_utils.c, Os_utils.h	Optional tools	Optional tools to manage a circular buffer, which can be used for debugging purposes. The functions are optional and are not used in the stack itself.

3.3 Important constraints for integrating an application

When integrating the PROFINET IO stack into a customer application, the following constraints have to be observed:

1. In a "PNIO_cbf_xxxx()" callback function, the application code to be performed should be as short as possible, because all callback events arriving from the CM are sequenced in a message queue, and the application code is called in the context of a PNPB interface task. This means a callback function cannot be called until the preceding callback function has finished.
2. **No** "PNIO_xxxx()" **API functions** should be called in a "PNIO_cbf_xxxx()" **callback function**. Permitted exceptions are "PNIO_rec_set_rsp_async()", "PNIO_get_last_error()", "PNIO_printf (debugging)" and plug/pull submodules in the context of the ownership indication.
3. Each user task from the context of which PROFINET IO service functions "PNIO_xxxx()" are called, must be created by "OsCreateThread()" and be started with "OsStartThread()". A message queue is thereby automatically assigned to the thread, which is used for (and exclusively reserved for) communication with the stack.
4. **Task priorities** of the PROFINET IO stack are specified in "os_taskprio.h". Platform-dependent changes are necessary here. However, the priority hierarchy among the PROFINET IO tasks may not be changed. Application tasks should be lower than the stack priorities, if possible. With higher priority application tasks, it must be noted that the **runtime performance of the stack** can be influenced negatively.

3.4 Porting the PROFINET IO software to another platform

For an ERTEC-based platform, porting to other operating systems is usually not necessary. We recommend using the eCos operating system platform that is already adapted, if possible. Porting is a typical use case for standard Ethernet controller-based platforms. The following section deals with adapting the PROFINET IO software to platforms of any kind. The application itself is not considered here, because it must be replaced in any case by a customer application (based on the application example). Depending on the component being replaced, different changes must be made in the software.
Basically, the following variants can be considered here:

- Replacement of the evaluation board with customer hardware based on the same microcontroller and the same operating system (simplest case) (see section 3.4.1 (Page 41))
- Use of other compilers (see section 3.4.2 (Page 42))
- Use of other operating systems (see section 3.4.3 (Page 43))

3.4.1 Porting to customer hardware with the same microcontroller and the same OS

To port the software to your own hardware platform without changing the operating system, you must adapt the board support package (BSP) to your hardware. Other changes to the OS adaption, BSP adaption or the example application (see Figure 2-2 (Page 16)) are usually not necessary.

3.4.2 Use of other compilers/linkers

The configuration of the compiler is done in the "auto_platform_select.h" file. A separate copy of this file exists in the "(...)\pn_ioddevkits\src\source\Platform" subdirectory for each platform. Only one "auto_platform_select.h" is included at a time by selecting the Include path. The auto_platform_select.h file is included in compiler.h.

3.4.2.1 Tool chain selection

As of development kit version 4.1, the selection of the platform is centrally mapped to a Define:

```
#define PNIOD_PLATFORM_xxxxx
```

wherebywhere xxxxx corresponds to the platform. The values for the defines are defined in the form of a bitmask, where each bit represents exactly one platform. This makes it possible to easily form parent defines, for example, for platforms with similar properties (example: platforms which all use the same operating system or the same compiler). Source code is made visible or hidden with:

```
#if (PNIOD_PLATFORM & PNIOD_PLATFORM_xxxxxxxxxxx)
  ....
#endif
```

The definition is made in the auto_platform_select.h file.

3.4.2.2 Big Endian / Little Endian

Note

In the current version of the development kit, only the little endian platform is officially tested and released

The definition is also made in the compiler.h file.

```
#define PNIO_BIG_ENDIAN          0          // Little Endian, e. g. ERTEC platform
#define PNIO_BIG_ENDIAN          1          // Big Endian
```

3.4.2.3 Data alignment requirements

The definition of the data alignment is often handled differently in different compilers. Some compilers use a #pragmapack() or #pragma unpack() instruction, whereby all definitions between two instructions are packed accordingly.

Other compilers expect a corresponding definition for each data structure that is located before or after the actual definition (depending again on the compiler).
For all three cases mentioned, the following mechanisms have been implemented in the PN stack:

- #include "sys_pck**x**.h", #include "sys_unpck.h"
- #define ATTR_PNIO_PACKED_PRE
- #define ATTR_PNIO_PACKED

Select just one of these options depending on the compiler. The other two should be implemented as an empty macro or empty header file. The ATTR_PNIO_PACKED or ATTR_PNIO_PACKED_PRE macros are implemented in the "(...)\pn_ioddevkits\src\source\sysadapt1\cfg\compiler.h" file; the #pragma pack/unpack instructions, on the other hand, are implemented in the file "(...)\pn_ioddevkits\src\source\sysadapt1\inc\sys_pck**x**.h" or "sys_unpck.h".

3.4.2.4 Data processing capacity

The software has only been ported for 32-bit microcontrollers. All data and address pointers are also 32 bits in length.

3.4.2.5 Memory management

For the IO stack, there are no particular specifications for memory management. This means the IO stack can be located as desired, taking into account the alignment and memory management requirements of the hardware. Because some LSA layers require an 8-byte alignment, an 8-byte alignment was implemented for "OsAllocX" and "OsFreeX" in the example system adaptation. This requirement is thereby met even for operating systems which themselves do not support this requirement.

For dynamic memory management, various memory pools can in principle be defined in the system adaptation in "os.h"; these are referenced in the software when memory is allocated. This mechanism is currently not used in the example portings, only the following pool has been defined:

```
#define MEMPOOL_DEFAULT        0              // may be cached
```

3.4.3 Use of other operating systems

The task priorities of the PROFINET IO tasks can be set in "os_taskprio.h". In so doing, the sequence of ascending priorities must not be changed. It must be noted that in some operating systems the lowest numeric value (priority = 0) represents the highest priority, while in others the reverse applies.

The file "xx_OS.C" contains an operating system abstraction interface, which the user must adapt to the particular operating system. The functions of the operating system interface are described in detail in section Interface to the operating system (Page 106).

Note

If your operating systems include a POSIX-API, we recommend using that one.

The ERTEC 200P kit already includes an adaptation to the POSIX interface, so it can be migrated with less effort to the POSIX-API of another OS.

3.5 Typical sequence of an IO device user program

Overview

The typical sequence of an IO device user program is divided into 3 phases:

- Initialization phase
- Productive operation
- Completion phase

IO data access:

- "Normal" IO data access in the RT or IRT mode (RT_CLASS3)
- IO data access from an isochronous application, only in IRT mode (RT_CLASS3)

Refer to the detailed information below.

3.5.1 Initialization phase

Description

The initialization phase is subdivided into several steps. Here, a distinction must be made between function calls that are made by the IO device user program and callback calls that are made by the IO interface.

Table 3- 8 API functions to be called during the startup phase

Step	Action	Objective
System startup		
0	System starts up and calls its main() function	Here, the first user task (usually the main() function) is called at the end of the system procedure from within the operating system.
1	PNIO_init()	"PNIO_init" initializes the OS interface, among other things, and must therefore be called once before all other PNIO functions.

Step	Action	Objective
2	OsCreateThread(MainAppl) OsCreateMsgQueue OsStartThread	With "OsCreateThread" the first PNIO user task, "MainAppl()", is started; it needs an OS message queue to communicate with the PNIO stack. **Note:** All additional PNIO API calls must be made from "MainAppl()" or from another task that has also been created by "OsCreateThread()".
PROFINET stack startup		
3	PNIO_setup()	Required defaults for the PNIO stack
4	PNIO_PDEV_setup	Function call: Application > IO Stack, synchronous
Creating instances for devices, APIs, modules, submodules		
5	PNIO_device_open()	Startup of the PNIO stack, startup of all PNIO tasks and allocation of resources, creation of a device instance
6	PNIO_sub_plug_list()	Insertion of the PROFINET IO submodules of the IO device according to a prescribed list. **Note:** All submodules for the PDEV and the DAP must be included in this list**.** IO submodules, on the other hand, can either be included in this list or later in list form (with PNIO_sub_plug_list) or plugged in later individually (with PNIO_sub_plug).
7	PNIO_set_dev_state()	Set device into OPERATE mode
Wait for establishment of connection by the IO controller		
8	Wait for a call of the PNIO_cbf_ar_connect_ind() callback function.	This callback is called by the IO interface as soon as an IO controller has established a connection to the IO device user program. When this callback is invoked, application relation global parameters are transferred to the IO device user program to provide information.
9	Wait for a call of the PNIO_cbf_ar_ ownership_ind() callback function.	The Ownership indication is called after the Connect indication disappears. Here, the application is passed a list of all submodules as well as their properties (slot, module/submodule ID, OwnerSessionKey, etc.). The OwnerSessionKey is set to 0 in this callback function only, if the application declines the ownership of a subslot, and thus does not want to process the submodule. Otherwise, the OwnerSessionKey (typically) remains unchanged. If an incorrect, incompatible submodule is plugged, the application must set the IsWrongSubmod parameter to PNIO_TRUE.
Parameter assignment of the submodules		
10	React to a call of the PNIO_cbf_rec_write() callback function.	This callback is invoked from the IO interface when an IO controller transfers a parameter assignment record for a submodule. When this callback is called, any parameter assignment data for each submodule is transferred to the IO device user program.
11	Wait for a call of the PNIO_cbf_param_end_ind() callback function.	This callback is called by the IO interface of each configured submodule as soon as an IO controller signals the end of the parameter assignment phase. In the return value, the application reports on whether the module is working correctly. The last of all PNIO_cbf_param_end_ind () calls is signaled using the MoreFollows = PNIO_FALSE parameter.
12	Wait for a call of the PNIO_cbf_ready_for_input_update() callback function.	In this PNIO_cbf_param_ end_ind() function, a one-time data exchange must be initiated using PNIO_initiate_data_write() and PNIO_initiate_data_read() (or similarly via the DBA interface). Refer to the description of the PNIO_cbf_ready_for_input_update() function for details.

Step	Action	Objective
13	PNIO_initiate_data_write()	With this call, the user program initiates a call of the "PNIO_CBF_DATA_WRITE()" callback so that the IO device user program can initialize the input data of the functional submodules and set the local status values to "GOOD". The local status values must be set to "BAD" for all non-functional submodules. **Note:** The PROFINET IO standard requires that the output data for all functional submodules are set to valid values, and that the local provider status for each one is set to "GOOD" before sending the ApplicationReady signal. This is achieved by a one-time call of PNIO_initiate_data_write in the PNIO_cbf_param_end_ind function (see above)
14	PNIO_initiate_data_read()	With this call, the user program initiates a call of the "PNIO_CBF_DATA_READ()" callback so it can set the local status values to "GOOD" for all output data of the functional submodules. The local status values must be set to "BAD" for all non-functional submodules. **Note:** The PROFINET IO standard requires that the local consumer status values be set to "GOOD" for all functional submodules before sending the ApplicationReady signal.
15	Wait for a call of the PNIO_cbf_ar_indata_ind() callback function	This callback is called by the IO interface as soon as an IO controller has transferred IO data for the first time. Signaling the start of cyclic data exchange

3.5.2 Productive operation

Overview

During productive operation, data is exchanged with the IO controller. This means:

- Reading/writing IO data (see also sections 4.1.9 (Page 81) and 4.1.10 (Page 83), respectively)
- Processing a read/write record request from the PNIO controller (see also section 4.1.8 (Page 76))
- Sending alarms to PNIO controllers and receiving their acknowledgments (see also sections 4.1.6 (Page 73) and 4.1.7 (Page 75))
- Callback events during the establishment/termination of connections at the IO device (see also section 3.11 (Page 57))

Details of the data traffic are explained below.

Reading RT and IRT IO data

IO data (output data from the perspective of the PNIO controller) are read in three steps:

Table 3- 9 API functions to be called for reading RT and IRT IO data

Step	Action	Objective
1	Wait for the PNIO_CP_CBE_TRANS_END_IND event	User program which stops sending the input data on the Ethernet. The associated callback function (here PNIO_cbf_trigger_io_exchange) is registered once by the application using "PNIO_CP_cbf_register_cbf". **Note**: Alternatively, the IO data exchange with the application can be performed asynchronously with RT and IRT, i.e. without synchronization by means of the TRANS_END event
2	PNIO_initiate_data_read()	Signals read request to the IO interface. This causes the IO interface to perform Step 3. This call returns only after all submodules have been processed in Step 3.
3	PNIO_cbf_data_read()	The IO interface calls this callback function for each submodule with output data and thereby transfers information such as the pointer to a data buffer containing the output data received from the IO controller.
4	PNIO_cbf_data_read_IOxS_only()	Function call: IO stack > Application, synchronous

Writing RT and IRT IO data

IO data (input data from the perspective of the PNIO controller) are written in three steps:

Table 3- 10 API functions to be called for writing RT and IRT IO data

Step	Action	Objective
1	Wait for the PNIO_CP_CBE_TRANS_END_IND event	With this event, the IO interface signals to the device application program the end of IO data transfer on the Ethernet. The associated callback function is registered once by the application by means of "PNIO_CP_cbf_register_cbf". **Note**: Alternatively, the IO data exchange with the application can be performed asynchronously with RT and IRT, i.e. without synchronization by means of the TRANS_END event
2	PNIO_initiate_data_write()	Signals a write request to the IO interface. This causes the IO interface to perform Step 3. This call returns only after all submodules have been processed in Step 3.
3	PNIO_cbf_data_write()	The IO interface calls this callback function for each submodule with input data and thereby transfers information such as the pointer to a data buffer to which the input data for the controller should be copied.
4	PNIO_cbf_data_write_IOxS_only()	Function call: IO stack > Application, synchronous

Processing a read/write record request from the PNIO controller

Processing a read record request

As soon as the IO interface receives a read record request from the IO controller, it invokes the callback function PNIO_cbf_rec_read(). The application can either provide the record data inside the callback function or can deliver it asynchronously at a later point in time.

- Synchronous reading of record data:

Table 3- 11 API functions to be called for synchronous reading of record data

Step	Action	Objective
1	PNIO_cbf_rec_read()	Read record request to the application. The application provides the data inside the callback function. After returning from the callback function, the request is completed from the application point of view.

- Asynchronous reading of record data:

Table 3- 12 API functions to be called for asynchronous reading of record data

Step	Action	Objective
1	PNIO_cbf_rec_read()	Read record request from the stack to the application. The application would like to provide the data asynchronously.
2	PNIO_rec_set_rsp_async()	The application notifies the stack that the response will occur asynchronously. "PNIO_rec_set_rsp_async" must be called inside the callback function.
3	PNIO_rec_read_rsp()	The application asynchronously transfers the requested record data to the stack. "PNIO_rec_read_rsp" can be called from any user task.

Processing a write record request

As soon as the IO interface receives a write record request from the IO controller, it invokes the callback function "PNIO_cbf_rec_write()". The application can signal to the stack of the completion of the write process synchronously when exiting the callback function or asynchronously at a later time.

- Synchronous writing of record data:

Table 3- 13 API functions to be called for synchronous writing of record data

Step	Action	Objective
1	PNIO_cbf_rec_write()	Write record request to the application. The application processes the data inside the callback function. After returning from the callback function, the request is completed from the application point of view.

- Asynchronous writing of record data:

Table 3- 14 API functions to be called for asynchronous writing of record data

Step	Action	Objective
1	PNIO_cbf_rec_write()	Write record request from the stack to the application. The application would like to provide the response asynchronously.
2	PNIO_rec_set_rsp_async()	The application notifies the stack that the response will occur asynchronously. "PNIO_rec_set_rsp_async" must be called inside the callback function.
3	PNIO_rec_write_rsp()	The application asynchronously signals to the stack about the completion of the request and includes status information. "PNIO_rec_write_rsp" can be called from any user task.

Sending alarms and receiving their alarm acknowledgments

Each time an alarm is sent, the IO device user program receives an alarm acknowledgment; this occurs when the IO interface calls the "PNIO_cbf_async_req_done()" function. The assignment of an acknowledgment to a given alarm is made with the type of alarm and the fault location "AR number/API/Slot/Subslot."

Note

Alarms can only be sent by the IO device user program when the PNIO_cbf_param_end() function is completed.

Callback events during the establishment/termination of connections at the IO device

When a connection is established, information is made available by the IO interface by means of a callback.

The table below lists the “flagged information” and the associated callback names.

Table 3- 15 API callback functions for establishing/terminating a connection

Callback name	Flagged information
PNIO_cbf_ar_connect_ind	Connection establishment request from the IO controller
PNIO_cbf_ar_ownership_ind	Specified configuration of the PNIO device, RT Class (RT Class 1/3) and other submodule properties
PNIO_cbf_rec_write_ind	Write a parameter record for a subslot
PNIO_cbf_param_end_ind	End of parameter assignment by PNIO controller
PNIO_cbf_indata_ind	Following the connection establishment, the valid output data from the PNIO controller is received for the first time.
PNIO_cbf_disconn_ind	DisconnectEvent – Close connection
PNIO_cbf_report_ARFSU_record	Notifies to device, if ARUUID has been changed/parameterization has been changed in engineering

Note

All these callbacks are called by the PROFINET library, generally in response to PROFINET IO controller actions.

3.5.3 Completion phase

(The shutdown of the PROFINET IO stack is currently not implemented.)

3.6 Basic data traffic in the IO device user interface

Description

The IO device functions have two basic mechanisms for data traffic:

Cyclic IO data traffic:

- Writing IO data
- Reading IO data

The IO data traffic is also accompanied by status information. This particular feature is described in the following section.

Acyclic data traffic:

- Reading and writing records
- Sending alarms and receiving their acknowledgements

Additional information on this topic can be found in section Callback mechanism (Page 57).

3.7 Cyclic IO data traffic of the IO device user interface

Basic mode of operation

When IO data are written or read by the IO device user program, only the local process image on the device is written or read; in doing so, no data are sent over the network.

Data traffic between the local process image and the IO controller is independently and cyclically processed by the underlying stack functions or the by the hardware. The details of this data traffic are specified in the configuration.

Note

The IO device user program is not required to read or write IO data in every bus cycle.

Note

The IO device user program is not required to access the process image more often than the configured cycle.

Note

The data of a submodule are always transferred consistently. According to the PROFINET IO standard, a PROFINET device (controller and device) must be able to consistently transfer at least 254 bytes. This should be taken into consideration in conjunction with a PROFINET IO controller.

IO data and data status

The quality of the IO data is described by the data status, which can take the values "GOOD" or "BAD".

Two data states are exchanged with every read or write:

- Local status (status of your IO device user program)
- Remote status (status of the communication partner)

3.7.1 Cyclic writing with status

Sequence of the write operation to the process image

The IO device user program initiates the write operation by calling the "PNIO_initiate_data_write()" function. The IO interface then calls the "PNIO_cbf_data_write" callback for each submodule that has been placed in service by the IO controller. The input data and the associated **local provider status** of this data are written into the local process image in this function.

Local status

Normally, the IO device user program sets the local provider status of the input data to "GOOD".

If the input data is corrupt or invalid, the IO device user program must set the local provider status to "BAD".
The communication partner could then, for example, output configured substitute values.

Remote status of the communication partner

The communication partner uses the "remote consumer status" to signal whether it was able to process the input data ("good"), or whether a fault is present in the communication partner.

When using the standard interface (IO data exchange initiated by "PNIO_initiate_data_read" and "PNIO_initiate_data_write"), this information is not transmitted to the application because it is usually not needed there. The remote consumer status of the input data can be read from the IOCR data with the DBA interface.

3.7.2 Cyclic reading with status

Sequence of the "PNIO_cbf_data_read()" function

The IO device user program initiates the read operation by calling the "PNIO_initiate_data_read()" function. Then the IO interface calls the "PNIO__cbf_data_read()" callback function for each submodule with output data that has been placed in service by the IO controller. With the call of the callback function, the output data and the associated **remote provider status** of the communication partner is read from the local process image (stack-internal) and transferred to the application.
In addition, the communication partner writes the **local consumer status** for these output data to the local process image.
Two states are thus involved in cyclic read operations:

Table 3- 16 Function "PNIO_cbf_data_read()": Status

Communication direction	Values
From the communication partner	• Output data • Remote provider status
To the communication partner	Local consumer status

Remote status of the communication partner

The communication partner uses the remote provider status to signal the quality of the output data ("GOOD" or "BAD").

If the communication partner reports the provider status "BAD", IO data in the IO device user program cannot be further processed; the IO device user program could then, for example, output substitute values.

Local status

Normally, the IO device user program sets the local consumer status to "GOOD".

However, if the IO device user program cannot continue processing the supplied output data, the local status must be set to "BAD". As soon as the communication partner receives this status, it can determine whether the output data it sent was able to be processed further.

3.7.3 Cyclic data communication using the optional DBA interface

The IO data can also be exchanged by using an optional DBA (Direct Buffer Access) interface. The application gains direct access to the IOCR and can directly write/read IO data and the IOxS to/from the individual submodules. This functionality provides performance advantages when there are a large number of submodules, because it is not necessary to execute a callback for every submodule. For more information, refer to section Cyclic data exchange by means of the optional DBA interface (Page 83).

The DBA interface can be used in all RT classes (RT, IRT).

3.8 IO data exchange for IRT class 3

The user interface is the same for RT and IRT. In both cases, the IO data exchange can be synchronized at startup by the registered callback function for the TRANS_END event (here PNIO_cbf_trigger_io_exchange).

3.9 Managing diagnostic data

Description

Diagnostics can be reported in the following ways with PROFINET IO:

- Standard channel diagnostics
- Extended channel diagnostics
- Manufacturer-specific diagnostics

The PROFINET stack automatically sends an entry "Diagnostic alarm - incoming" to the PROFINET IO controller when a new diagnostic entry is received. When the diagnostic entry is cleared, the corresponding "Diagnostic alarm - outgoing" is sent.

Note

Read the current diagnostic guidelines issued by the PROFIBUS/PROFINET User Organization and available for download from their website. This document ("PNIO_Diagnosis_7142_V15_Feb20.pdf") is also available in the subdirectory "(...)\doc\PNO documents".

3.9.1 Channel diagnostic data

In PROFINET IO , a submodule can consist of several channels. Multiple “channel diagnostic data" can exist for each channel. The IO device user program can create them in the submodule using the "PNIO_diag_channel_add()" function.

If "channel diagnostic data" is no longer valid, the IO device user program must clear the diagnostic entry from the submodule using the "PNIO_diag_channel_remove()" function.

The following functions are available for managing diagnostic data:

Table 3- 17 API functions to be called for the creation of a diagnostic record

Function	Objective
PNIO_diag_channel_add()	Stores the channel diagnostic data in the subslot
PNIO_diag_channel_remove()	Removes the channel diagnostic data from the subslot

Function	Objective
PNIO_ext_diag_channel_add()	Stores the extended channel diagnostic data in the subslot
PNIO_ext_diag_channel_remove()	Removes the extended channel diagnostic data from the subslot

Setting channel diagnostic data

Channel diagnostic data is set in two steps:

Table 3- 18 API functions to be called for the activation of a created diagnostic record

Step	Action	Objective
1	PNIO_diag_channel_add()	Stores the channel diagnostic data in the submodule. The stack automatically generates a "Diagnostic alarm - incoming" for the IO controller.
2	PNIO_cbf_async_req_done()	"Diagnostic alarm - incoming" - evaluate acknowledgment.

Clearing channel diagnostic data

Channel diagnostic data is cleared in two steps:

Table 3- 19 API functions to be called for the removal of a diagnostic record

Step	Action	Objective
1	PNIO_diag_channel_remove()	Clears the channel diagnostic data from the submodule. The stack automatically generates a "Diagnostic alarm - outgoing" for the IO controller.
2	PNIO_cbf_async_req_done()	"Diagnostic alarm - outgoing" - evaluate acknowledgment.

3.9.2 Manufacturer-specified diagnostic data

"Manufacturer-specific diagnostic data" offers the IO device user program the option of storing its own manufacturer-specific diagnostic data for a submodule. There is no structure definition within the "manufacturer-specific diagnostic data". (see References (Page 132) /5/)

Note

It is strongly recommended to use the standard or extended diagnostics rather than the manufacturer-specific diagnostics.

The following functions are available for managing this diagnostic data:

Table 3- 20 API functions to be called for the creation of a generic diagnostic record

Function	Objective
PNIO_diag_generic_add()	Stores the manufacturer-specific diagnostic data in the subslot. The stack automatically generates a "Generic alarm - incoming" for the IO controller.
PNIO_diag_generic_remove()	Removes the manufacturer-specific diagnostic data from the subslot. The stack automatically generates a "Generic alarm - outgoing" for the IO controller.

Setting manufacturer-specific diagnostic data

Manufacturer-specific diagnostic data is set in two steps:

Table 3- 21 API functions to be called for the activation of a generic diagnostic record

Step	Action	Objective
1	PNIO_diag_generic_add()	Stores the manufacturer-specific diagnostic data in the subslot. The stack automatically generates a "Generic alarm - incoming" for the IO controller.
2	PNIO_cbf_ async_req_done()	Generic alarm- incoming - evaluate acknowledgment.

Clearing manufacturer-specific diagnostic data

Manufacturer-specific diagnostic data is cleared in two steps:

Table 3- 22 API functions to be called for the removal of a generic diagnostic record

Step	Action	Objective
1	PNIO_diag_generic_remove()	Removes the manufacturer-specific diagnostic data from the submodule. The stack automatically generates a "Generic alarm - outgoing" for the IO controller.
2	PNIO_cbf_ async_req_done()	Generic alarm - outgoing - evaluate acknowledgment.

3.10 Special features when inserting and removing modules during productive operation

Alarm for pulling submodules

The PROFINET stack generates a PROFINET IO pull alarm as soon as the IO device user program pulls a module or a submodule with the following functions:

- PNIO_sub_pull()

Alarm for plugging submodules

The IO interface generates a PROFINET IO plug alarm as soon as the IO device user program plugs in a module or a submodule with the following functions:

- PNIO_sub_plug()

Note

Modules may not be plugged or pulled during the time between the conclusion of "PNIO_cbf_ar_ownership_ind" and the conclusion of the "PNIO_cbf_param_end_ind" function.

Reassignment of parameters after plugging

The IO controller reassigns parameters for the associated submodule after each "PNIO_sub_plug()". This means that the PNIO stack calls the "PNIO_cbf_rec_write()" function for each parameter assignment record transferred by the IO controller.

The IO interface signals the end of parameter assignment by calling the "PNIO_cbf_param_end()" function.

After parameter assignment, the IO device user program determines whether the inserted submodule is functional with the transferred parameter assignment.

- If "YES", the IO device user program must set the input data to be sent and the local status for the inputs and outputs of this submodule to "GOOD". After this, the IO device user program must close the "PNIO_cbf_param_end()" function with Return (PNIO_SUBMOD_STATE_RUN).
- If "NO", the IO device user program must set the local status for the inputs and outputs of this submodule to "BAD" and then close the "PNIO_cbf_param_end()" function with Return (PNIO_SUBMOD_STATE_STOP). If the module can provide valid data for the running AR at a later point, the status must be set to "GOOD" and a return-of-submodule alarm triggered (see next section).

3.10.1 Special features with "Return of submodule"

Description

When a fault occurs in an inserted submodule, the IO device user program must leave the local status for the inputs and outputs as "BAD". As a result, the input and output data are no longer valid for the user program on the assigned IO controller.

If the submodule is functional again, the IO device user program must set the local status for the inputs and outputs to "GOOD". Then the IO device user program must signal the transition from "BAD" to "GOOD" to the IO controller by calling the "PNIO_ret_of_sub_alarm_send()" function. The IO controller does not reassign parameters for the submodule due to the "Return of submodule" alarm.

The submodule is thus functional again.

3.11 Callback mechanism

Operating principle

Callback functions are specified by the PNPB component of the PNIO stack.

A callback event is an asynchronous event that is started by the PNIO stack. It interrupts the flow of the user program, and starts the callback function in a separate thread. Synchronization techniques are therefore required.

Callback functions in the IO device

The table below shows the callback events and callback event types in the IO device. It also shows how you can register a callback function and how a callback event is triggered.

Table 3- 23 Overview of the callback functions in the IO device

Callback event (asynchronous)	Callback event type	Triggered by ...
Reading data	PNIO_cbf_data_read	User program by calling PNIO_initiate_data_read
Writing data	PNIO_cbf_data_write	User program by calling PNIO_initiate_data_write
Reading a record	PNIO_cbf_rec_read	IO controller
Writing a record	PNIO_cbf_rec_write	IO controller
Acknowledgment for an alarm send request	PNIO_cbf_async_req_done	User program by calling: • PNIO_process_alarm_send • PNIO_diag_channel_add • PNIO_ext_diag_channel_add • PNIO_ret_of_sub_alarm_send • PNIO_upload_retrieval_alarm_send

Callback event (asynchronous)	Callback event type	Triggered by ...
Alarm from IO controller to device	PNIO_cbf_dev_alarm_ind	Alarms from IO controller to the device (reserved, currently not implemented)
Comparison of the specified configuration	PNIO_cbf_check_ind	Alarms from IO controller to the device (currently not implemented)
Connection establishment step 1	PNIO_cbf_ar_connect_ind	PNPB
Connection establishment step 2	PNIO_cbf_ar_ownership_ind	PNPB
Connection termination	PNIO_cbf_ar_disconn_ind	PNPB
Parameter assignment phase completed	PNIO_cbf_param_end_ind	PNPB
Initial reading of output data from the controller	PNIO_cbf_ready_for_input_update_ind	PNPB
Start LED flashing	PNIO_cbf_start_led_blink	PNPB
Stop LED flashing	PNIO_cbf_stop_led_blink	PNPB
Save new IP suite retentively	PNIO_cbf_save_ip_addr	PNPB
Report IP suite change to application	PNIO_cbf_report_new_ip_addr	PNPB
Report change of FSU parameters	PNIO_cbf_report_ARFSU_record	PNPB
Save new station name retentively	PNIO_cbf_save_station_name	PNPB
Save REMA data	PNIO_cbf_store_rema_mem	PNPB
Cyclic data transfer completed	PNIO_CP_CBE_TRANS_END_IND	PNDV

Note

When compiling your user program, link standard libraries with multi-threading capability.

Note

Function calls within a callback function are prohibited, if they lead to a call of the same callback function.

This means the functions of the IO device applications programming interface described here, for example, cannot be called unless explicitly allowed.

Runtime coordination for callbacks

A callback function can interrupt the IO device user program at any time. Callback functions for different events can also interrupt one another. A callback function must therefore be designed for multiple simultaneous processing (reentrant) because it can be called from various threads. **In practice, this means that the writing and reading of shared tags must be protected by synchronization mechanisms.**

Avoid waits in callback functions, particularly when entering critical sections. This can block a subsequent call to this and other callback functions. Instead, you should keep your stored data separate.

4 Interface description

4.1 Upper layer interface functions for the application

Functions to be implemented by the user

All functions with the designation "Function call: IO stack > Application" are not called by the application; instead they are called by the stack and must be implemented by the **user**. All of these functions have names starting with the prefix "PNIO_cbf_" because, logically speaking, a callback function is involved. For all of these functions, a simple example implementation is available under example applications which generally must be extended.

Table 4- 1 Functions to be implemented by the user

Function	See section ...
Setting the device name and IP suite	
PNIO_cbf_save_station_name()	4.1.2.1 (Page 63)
PNIO_cbf_save_ip_addr()	4.1.2.2 (Page 64)
PNIO_cbf_report_new_ip_addr()	4.1.2.3 (Page 64)
Storage of retentive data (REMA)	
PNIO_cbf_store_rema_mem()	4.1.3.1 (Page 66)
IO device configuration	
PNIO_cbf_new_plug_ind()	4.1.4.4 (Page 69)
PNIO_cbf_new_pull_ind()	4.1.4.5 (Page 69)
Sending and receiving alarms	
PNIO_cbf_dev_alarm_ind()	4.1.6.4 (Page 75)
Acknowledgment of asynchronous functions	
PNIO_cbf_async_req_done()	4.1.7.1 (Page 75)
Reading and writing records	
PNIO_cbf_rec_read()	4.1.8.1 (Page 77)
PNIO_cbf_rec_write()	4.1.8.2 (Page 78)
PNIO_cbf_data_read_IOxS_only()	4.1.8.7 (Page 80)
PNIO_cbf_data_write_IOxS_only()	4.1.8.8 (Page 81)
Cyclic data exchange using standard interface (SI)	
PNIO_cbf_data_write(), PNIO_cbf_data_read()	4.1.9.1 (Page 81)
Receiving events and alarms	
PNIO_cbf_ar_connect_ind()	4.1.11.1 (Page 86)
PNIO_cbf_ar_ownership_ind()	4.1.11.2 (Page 87)
PNIO_cbf_ar_indata_ind()	4.1.11.3 (Page 87)
PNIO_cbf_ar_disconn_ind()	4.1.11.4 (Page 88)
PNIO_cbf_param_end_ind()	4.1.11.5 (Page 88)
PNIO_cbf_ready_for_input_update_ind()	4.1.11.6 (Page 89)

Function	See section ...
Error handling	
PNIO_Log()	4.1.14.2 (Page 94)
Other functions	
PNIO_printf()	4.1.15.1 (Page 96)
PNIO_TrcPrintf()	4.1.15.2 (Page 96)

Synchronous and asynchronous functions

In the case of a synchronous function, execution is already completed when the function returns.

In the case of asynchronous functions, however, completion of the execution is indicated by means of a callback function.

Whether a function operates synchronously or asynchronously is indicated in the description for the individual functions.

4.1.1 Functions for system startup

4.1.1.1 PNIO_init

PNIO_init()			**Function call: Application > IO Stack, synchronous**
This function initializes the adaptation interface from the PNIO stack to the operating system (OS) interface and the BSP interface. It must therefore be called first during startup once before any other PNIO function is called, for example, before the first PNIO task is created by "OsCreateThread()".			
Input	-	-	
Output	-	-	

4.1.1.2 PNIO_setup

PNIO_setup()			**Function call: Application > IO Stack, synchronous**
Starts the IO stack. This function is called once during startup from the PNIO task that had to be created by "OsCreateThread()". Station name, station type and IP suite (IP address, subnet mask, default router address) must be specified as transfer parameters.			
Input	PNIO_INT8*	pStationName	Pointer to the station name (may be a non-NULL-terminated string)
	PNIO_UINT32	StationNameLen	Length of the station name string
	PNIO_INT8*	pStationType	Pointer to the station type (NULL-terminated string)
	PNIO_UINT32	IpAddr	IP address of the device
	PNIO_UINT32	SubnetMask	IP subnet mask
	PNIO_UINT32	DefRouterAddr	IP default router
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.1.3 PNIO_device_open

PNIO_device_open()			**Function call: Application > IO Stack, synchronous**
Creates a device instance. The function is called once during startup (after "PNIO_setup()") for each device instance. The following parameters are transferred: device ID, vendor ID, instance ID, max. number of ARs, the device annotation and (optionally for reasons of interface compatibility to the EB 200P and CP1616, configurable using "#define" in compiler.h) a list of callback functions. The stack creates a handle for the device and writes it to the address specified by "pDevHndl". The device handle must be saved in the application and specified as a parameter for most of the "PNIO_" functions. **Note**: The multi-device functionality is currently not implemented; however, the handle must still be specified correctly.			
Input	PNIO_UINT16	VendorId	Vendor ID for the device; must be requested from the PROFIBUS user organization.
	PNIO_UINT16	DeviceId	Device ID; must be unique within a vendor's PNIO products.
	PNIO_UINT16	InstanceId	Instance ID for the device (currently only InstanceId = 1 is permitted)
	PNIO_ANNOTATION*	pDevAnnotation	Annotation structure; contains device type, article number, product version, etc.
	PNIO_SNMP_LLDP*	pSnmpPar	Pointer of type "PNIO_SNMP_LLDP" to SNMP objects that are registered in the LLDP MIB.
	PNIO_BOOL	MrpCapabilityActive	"PNIO_TRUE": MRP capability activated, "PNIO_FALSE": MRP capability disabled.
	PNIO_UINT32*	pDevHndl	Pointer to address in which the IO stack returns the device handle to the application.
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.1.4 PNIO_async_appl_rdy

PNIO_async_appl_rdy()			**Function call: Application > IO Stack, synchronous**
The "PNIO_async_appl_rdy()" function is only required if the ApplicationReady for a submodule should be delayed, because the parameter assignment for this submodule is not yet complete. Normally, the information regarding whether or not a submodule has started correctly after parameter assignment is already passed to the PNIO stack in the return value of the callback function "PNIO_cbf_param_end_ind()". For this, the application returns "PNIO_SUBMOD_STATE_RUN" (submodule OK) or "PNIO_SUBMOD_STATE_STOP" (submodule not OK) in the return value. The stack can then automatically generate an ApplicationReady frame for the PNIO controller and include it in the Moduldiffblock contained in the frame in the event of an error. However, if the parameter assignment of a submodule takes longer and the "PNIO_cbf_param_end_ind()" callback function should not be delayed, the ApplicationReady for this module can also be sent later. For this, "PNIO_cbf_param_end_ind()" first supplies the return value "PNIO_SUBMOD_STATE_APPL_RDY_FOLLOWS". Once the parameter assignment is complete, this information is "sent later" to the affected submodules using "PNIO_async_appl_rdy()".			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT16	ArNum	Number of the affected AR
	PNIO_UINT32	Api	API number
	PNIO_UINT16	SlotNum	Slot number
	PNIO_UINT16	SubslotNum	Subslot number
	PNIO_SUBMOD_STATE	SubState	Defines whether or not the module has started correctly. Possible values are: • "PNIO_SUBMOD_STATE_RUN" • "PNIO_SUBMOD_STATE_STOP"

PNIO_async_appl_rdy()			**Function call: Application > IO Stack, synchronous**
	PNIO_BOOL	MoreFollows	- "PNIO_TRUE": The "PNIO_async_appl_rdy()" calls for additional submodules of this AR follow. The requests are only cached in the PNIO stack. - "PNIO_FALSE": There are no further "PNIO_async_appl_rdy()" calls. All previous cached requests (MoreFollows = PNIO_TRUE) in the PNIO stack are processed, and the ApplicationReady frame for the PNIO controller is generated and sent.
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.1.5 PNIO_device_close

PNIO_device_close()			**Function call: Application > IO Stack, synchronous**
Not yet supported.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
Output	PNIO_UINT32		Execution status: "PNIO_OK"

4.1.1.6 PNIO_CP_register_cbf

PNIO_CP_register_cbf()			**Function call: Application > IO Stack, synchronous**
Callback functions can be registered for cyclic events in the PNIO stack with "PNIO_register_cbf()" to synchronize the application with the data transfer on the bus. Currently the event "PNIO_CP_CBE_TRANS_END_IND" is implemented. This function notifies the application that the data transfer for the current IO cycle has finished. The application can now access the IO data using "PNIO_initiate_data_read()" or "PNIO_initiate_data_write()".			
Input	PNIO_CP_CBE_TYPE	CbeType	Specifies the event for which the callback is called. Currently the event "PNIO_CP_CBE_TRANS_END_IND" is implemented.
	PNIO_CP_CBF	pCbf	Start address of the application function to be called by the PNIO stack when the above-named event occurs.
Output	PNIO_UINT32		Execution status: "PNIO_OK"

4.1.1.7 PNIO_PDEV_setup()

PNIO_pdev_setup ()			**Function call: Application > IO Stack, synchronous**
Setup of PDEV parameters.			
Input	PNIO_SUB_LIST_ENTRY *	pStationName	Pointer to the plugged submodules, including PDEV
	PNIO_UINT32	StationNameLen	number of entries in pPioSubList
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.2 Setting the device name and IP suite

The Ethernet parameters (IP address, subnet mask, default router address) of the IO device can be set by a PROFINET IO controller via Ethernet. The station name of the device must have been set beforehand with the configuration tool.

For transferring this information to the application, functions which the user must implement are called by the IO stack. The application must store these data in non-volatile memory (NV RAM, Flash EPROM, etc.). The data is transferred again to the stack at the next system startup by means of the following function

- "PNIO_setup()"

To transfer the station name a function frame is placed in "iodapi_event.c" for the following function, which must be implemented by the user:

- "PNIO_cbf_save_station_name()"

Setting of the Ethernet parameters is basically performed in the same way by calling the function

- "PNIO_cbf_save_ip_addr()"

A blinking function can be started in the engineering tool. The addressed IO device is identified visually by a flashing LED. Activation of the LED is platform-dependent and, therefore, not contained directly in the IO stack. In this case, the IO stack calls the following functions, which the user must implement accordingly:

- "PNIO_cbf_start_led_blink" (flash frequency)
- "PNIO_cbf_stop_led_blink()"

With the following function, the factory settings must be restored:

- "PNIO_cbf_reset_factory_settings()"

In development kit version V4.5 and higher the IP suite and the device name optionally can be set also from the application. In this case IP suite and device name are set non-remanent.

To store them retentively, the application has to store them in NV memory.

To change temporarily the IP address or device name, the application has to call

- "PNIO_change_ip_suite()"
- “PNIO_change_device_name“

4.1.2.1 PNIO_cbf_save_station_name

PNIO_cbf_save_station_name()			**Function call: IO stack > Application, synchronous**
If a new station name for the device has to be assigned for the device via Ethernet, the "PNIO_cbf_save_station_name()" function is called by the IO stack. The application now must store the transferred station name in non-volatile memory, if the retentive parameter is not equal to 0. The value is read by the application from the non-volatile memory at the next system startup and transferred to the stack again with the "PNIO_setup()" function.			
Input	PNIO_INT8*	pStationName	Pointer to the string that contains the station name. (The station name does not necessarily have to be null-terminated.)
	PNIO_UINT16	NameLength	Length of the string in bytes

PNIO_cbf_save_station_name()			Function call: IO stack > Application, synchronous
	PNIO_UINT8	Remanent	<> 0: Data must be stored retentively == 0: Value cannot be saved retentively and a name already stored must be deleted
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.1.2.2 PNIO_cbf_save_ip_addr

PNIO_cbf_save_ip_addr()			Function call: IO stack > Application, synchronous
f the IP suite stored in flash has to be changed, then "PNIO_cbf_save_ip_addr()" function is called by the PN stack. This happens if the IP suite data in the non-volatile memory (NV-memory) either has to be updated or to be deleted (set to ZERO). For example, according to the PN specification the IP suite in NV-memory has to be set to ZERO, if a DcpSetIP request with option non-remanent has been received on Ethernet. If PNIO_cbf_save_ip_addr() is executed, the application only has to store the new IP suite data into the NV-memory. **Note**: PNIO_cbf_save_ip_addr will be called only if a modification of the IP suite in NV-data is necessary. However the function PNIO_cbf_report_new_ip_addr() is called additionally at every IP suite change, to notify the application about that event. The values from NV-memory are read back by the application at the next system startup and transferred to the stack again with the "PNIO_set_eth_par()" function, so the PN stack can start up with the correct IP parameters.			
Input	PNIO_UINT32	NewIpAddr	New IP address
	PNIO_UINT32	SubnetMask	New value for subnet mask
	PNIO_UINT32	DefRouterAddr	New value for default router
	PNIO_UINT8	Remanent	<> 0: Data must be stored retentively in NV-memory == 0: Values already stored must be deleted (set to ZERO)
Output	PNIO_UINT32	return	"PNIO_OK," "PNIO_NOT_OK"

4.1.2.3 PNIO_cbf_report_new_ip_addr

PNIO_cbf_report_new_ip_addr()			Function call: IO stack > Application, synchronous
This function will be called by the PN stack if a new IP suite has to be activated in the IP stack. It always contains the new IP suite data. This is only a report function, that means from the PROFINET point of view no more action by the application is required and the implementation may contain only a return statement. **Note**: The function PNIO_cbf_save_ip_addr() may be called additionally, depending on whether the IP-suite data in the NV-memory has to be updated or not.			
Input	PNIO_UINT32	NewIpAddr	New IP address
	PNIO_UINT32	SubnetMask	New value for subnet mask
	PNIO_UINT32	DefRouterAddr	New value for default router
Output	PNIO_UINT32	return	"PNIO_OK," "PNIO_NOT_OK"

4.1.2.4 PNIO_change_ip_suite

PNIO_change_ip_suite()	Function call: Application > IO Stack, synchronous
Temporarily changes the IP suite inside the PROFINET stack. The new values are not stored inside the NV-data. The function will be executed only if no AR is running, otherwise PNIO_NOT_OK will be returned.	

PNpInput	PNIO_UINT32	NewIpAddr	New IP address
	PNIO_UINT32	SubnetMask	New value for subnet mask
	PNIO_UINT32	DefRouterAddr	New value for default router
	PNIO_UINT32	return	"PNIO_OK," "PNIO_NOT_OK"
Output			

4.1.2.5 PNIO_change_device_name

PNIO_change_device_name()			**Function call: Application > IO Stack, synchronous**
Temporarily changes the device name inside the PROFINET stack. The new value is not stored inside the NV data. The function will be executed only if no AR is running, otherwise PNIO_NOT_OK will be returned.			
Input	PNIO_INT8*	pStationName	Pointer to the string that contains the station name. (The station name does not necessarily have to be null-terminated.)
	PNIO_UINT16	NameLength	Length of the string in bytes
	Output	PNIO_UINT32	return
Output	PNIO_UINT32	return	must be "PNIO_OK"

4.1.2.6 PNIO_cbf_start_led_blink()

PNIO_cbf_start_led_blink()			**Function call: IO stack > BSP, synchronous**
If the flashing function is started in the engineering tool, the IO stack calls this function. The application can then put an LED (if present) into flashing mode at the specified frequency. The flashing process lasts about 3 seconds, and then the stack automatically calls "PNIO_cbf_stop_led_blink()" which ends the flashing process.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	PortNum	Port number (1 to n)
	PNIO_UINT32	Frequency	Specified flashing frequency, in Hertz
Output	PNIO_UINT32	return	must be "PNIO_OK"

4.1.2.7 PNIO_cbf_stop_led_blink

PNIO_cbf_stop_led_blink()			**Function call: IO stack > BSP, synchronous**
Turns the flashing mode of the LED off again.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	PortNum	Port number (1 to n)
Output	PNIO_UINT32	return	Must be "PNIO_OK"

4.1.2.8 PNIO_cbf_reset_factory_settings

PNIO_cbf_reset_factory_settings()			**Function call: IO stack > BSP, synchronous**
Reset to factory settings The application must reset all non volatile parameters (device name, IP suite, REMA data, etc.) to factory settings. After this the system must be restarted by the application so that the PNIO stack will reset its internal data.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
Output	PNIO_UINT32	return	Must be "PNIO_OK"

4.1.3 Storage of retentive data (REMA)

In addition to the device name and IP suite, the records of the physical device (PDEV records) must be stored on the device in non-volatile memory. After the creation of the AR, the PDEV records are transferred from the PNIO controller to the device by means of "Record-Write" functions.

The records are temporarily stored by the PNIO stack and processed there. When all PDEV records have been received, they are recorded by the PNIO stack in a contiguous memory area and transferred to the application for persistent storage by means of a single call. The application therefore need not interpret the PDEV records, but only has to accept the entire data block and store it in non-volatile memory. The transfer of the PDEV data block from the PNIO stack is performed with the function

- "PNIO_cbf_store_rema_mem()".

A pointer to the data and the data length are passed as call parameters.

The next time the device starts up, the PNIO stack queries this information from the application. For this, the stack calls the function

- "PNIO_cbf_restore_rema_mem()"

The address of a pointer (**ppMem) is passed as a call parameter. The application enters the actual address of the REMA data there. A pointer to the data length is also passed, the application enters the actual data length there. It should be noted that the REMA data is not copied in this case and must therefore remain valid (static data) even after "PNIO_cbf_restore_rema_mem()" is completed.

4.1.3.1 PNIO_cbf_store_rema_mem

PNIO_cbf_store_rema_mem()			**Function call: IO stack > Application, synchronous**
Here all received PDEV records are transferred to the application in a contiguous data block for non-volatile storage. The application need only store the data block without change or interpretation in non-volatile memory and transfer it back to the stack at the next startup using "PNIO_restore_rema_mem()".			
Input	PNIO_UINT32	MemSize	Size of the data block in bytes
	PNIO_UINT8*	pMem	Pointer to the data block
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.1.3.2 PNIO_cbf_restore_rema_mem

PNIO_cbf_restore_rema_mem()			**Function call: Application > IO Stack, synchronous**
With this function the application transfers the PDEV record data block, which has been stored in non-volatile memory, back to the PNIO stack. This function must be called once during application startup, after the stack has started up, and the PDEV modules have been inserted.			
Input	PNIO_UINT32*	pMemSize	Pointer to the data block size in bytes, the application must enter the actual data length here.
	PNIO_UINT8**	ppMem	Address of the pointer to the data block. The application enters the actual address of the REMA data here. **The REMA data must be static, which means it must remain valid even after "PNIO_cbf_restore_rema_mem" is completed.**
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.1.3.3 PNIO_cbf_report_ARFSU_record

PNIO_cbf_restore_rema_mem()			Function call: Application > IO Stack, synchronous
This function is called from the PN-stack, when a new ARFSU write record has been received from the CPU. It notifies the application, if FSU has been enabled and if the ARFSU_UUID, stored in the NV-Data, has been changed or not. Additionally, the PN-stack stores the new received ARFSU-UUID in the non-volatile data by calling Bsp_nv_data_store.			
Input	PNIO_UINT8	ARFSU_enabled	PNIO_ARFSU_ENABLED, PNIO_ARFSU_DISABLED
	PNIO_UINT8	ARFSU_changed	PNIO_ARFSU_CHANGED**,** PNIO_ARFSU_NOT_CHANGED
Output	--	--	-

4.1.4 IO device configuration

4.1.4.1 PNIO_sub_plug

PNIO_sub_plug()			**Function call: Application > IO Stack, synchronous**
Insertion of a new submodule into a subslot. The function is called during startup to specify the current configuration to the IO stack. It can also be called during operation in the event of changes to the current configuration, which means when a submodule that has failed or has been removed is once again functional. In this case, a plug alarm automatically sent by the IO stack to the IO controller. A list of modules can be inserted by setting the parameter "MoreFollows" = "PNIO_TRUE". In this case, the modules can be stored temporarily in PNDV and passed later to the CM at the next insertion call with "MoreFollows PNIO_TRUE =". The feedback in "pError" is therefore only valid thereafter and can then be queried by the application. **Note**: During startup, the DAP and PDEV data "**PNIO_sub_plug_list()**" **must** be inserted first. Only then may additional modules be plugged in, either as additional entries in the "pIoSublist" submodule list or individually using the "PNIO_sub_plug()" function.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. Slot numbers 1 to n are permitted; the maximum slot number was specified in "PNIO_setup()". "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT32	ModIdent	Module identifier (stored in the GSD file)

PNIO_sub_plug()			**Function call: Application > IO Stack, synchronous**
	PNIO_UINT32	SubIdent	Submodule identifier (stored in the GSD file)
	PNIO_UINT32	InputDataLen	Length of Input data
	PNIO_UINT32	OutputDataLen	Length of Output data
	PNIO_IM0_SUPP_ENUM	Im0Support	Specifies whether IM0 is supported and in which form, see enum "PNIO_IM0_SUPP_ENUM" in the "pniousrd.h" file.
	IM0_DATA*	pIm0Dat	If the module supports IM0 (Im0Support <> PNIO_IM0_NOTHING), there is a pointer to the IM0 data here. Further handling of the IM0 data is perform internally in the stack.
	PNIO_UINT8	IopsIniVal	For submodules without IO data (e.g. PDEV submodules), the initial IOPS value for input modules is passed here (according to the PNIO standard, a submodule without data reacts like an input module with a data length of 0).
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.4.2 PNIO_sub_plug_list

PNIO_sub_plug_list()			**Function call: Application > IO Stack, synchronous**
Insert a list of submodules in subslots. The function is called during startup to specify the current configuration to the IO stack. It can also be called during runtime in case the current configuration is changed. In this case, plug alarm are automatically sent by the IO stack to the IO controller. **Note**: During startup, the DAP and PDEV data **must** be inserted first with the "**PNIO_sub_plug_list()**". Only then may additional modules be plugged in, either as additional entries in the "pIoSublist" submodule list or individually using the "PNIO_sub_plug()" function. Either the DAP or the interface (subslot 0x8000) must serve as an IM0 proxy for the device, which means it must have its own IM0 data and the element "Im0Support" = (PNIO_IM0_SUBMODULE + PNIO_IM0_DEVICE) needs to be set in the submodule list. You can find an application example of this in file "usriod_main.c", structure "IoSubList []".			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_SUB_LIST_ENTRY *	pIoSubList	List of submodules of the type "PNIO_SUB_LIST_ENTRY". It includes the slot number, module and submodule IDs, IM0 support yes/no.
	PNIO_UINT32	NumOfSublistEntries	Number of entries in the list of submodules.
	PNIO_IM0_LIST_ENTRY *	pIm0List	List of IM0 data for submodules that have their own IM0 data.
	PNIO_UINT32	NumOfIm0ListEntries	Number of entries in the list of IM0 data.
	PNIO_UINT32*	pStatusList	List of status feedback ("PNIO_OK", "PNIO_NOT_OK") for each submodule in "pIoSubList". The status list therefore has the same number of entries as the submodule list.
Output	PNIO_UINT32	return	Group status: "PNIO_OK" if all individual feedback messages in "pStatusList" also contain "PNIO_OK"; otherwise "PNIO_NOT_OK" is reported back.

4.1.4.3 PNIO_sub_pull

PNIO_sub_pull()			**Function call: Application > IO Stack, synchronous**
Removal of an inserted submodule. In this case, a pull alarm is automatically sent by the IO stack to the IO controller.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)

PNIO_sub_pull()			**Function call: Application > IO Stack, synchronous**
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. Slot numbers 1 to n are permitted; the maximum slot number was specified in "PNIO_setup()". "PNIO_ADDR_GEO" must be entered as the type.
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.4.4 PNIO_cbf_new_plug_ind ()

PNIO_cbf_new_plug_ind ()			**Function call: IO stack > Application, synchronous**
The Plug Indication of a module			
Input	PNIO_DEV_ADDR *	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. Slot numbers 1 to n are permitted
	PNIO_UINT32	InputDataLen	submodule input data length
	PNIO_UINT32	OutputDataLen	submodule output data length
Output	PNIO_VOID	return	

4.1.4.5 PNIO_cbf_new_pull_ind ()

PNIO_cbf_new_pull_ind ()			**Function call: IO stack > Application, synchronous**
The Pull Indication of a module			
Input	PNIO_DEV_ADDR *	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. Slot numbers 1 to n are permitted
Output	PNIO_VOID	return	

4.1.5 Storing diagnostic data in the subslot

4.1.5.1 PNIO_diag_channel_add

PNIO_diag_channel_add()			**Function call: Application > IO Stack, synchronous**
Downloads a diagnostic record into a subslot. If the device is the owner of this subslot in an AR, a "Diagnostic alarm - incoming" is automatically sent to the IO controller. The diagnostic record can be removed with the "PNIO_diag_channel_remove()" function once the problem is rectified. The value DiagTag is a user defined value <> 0, that distinguishes different alarms for one subslot, that are valid at the same time. So it must be always unique inside one subslot. If only one alarm at a time can be available, a fix value (e.g. 1) can be used. Otherwise the application has to manage the DiagTag values and has to take care, that inside this subslot the DiagTag is always unique.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT16	ChannelNum	Channel number, content, and structure; see also "ChannelNumber" in /1/
	PNIO_UINT16	ErrorNum	Error number, see also /1/

	DIAG_CHANPROP_DIR	ChainDir	Data direction (IN/OUT/INOUT), see enum "DIAG_CHANPROP_DIR" in the file "pniousrd.h"
	DIAG_CHANPROP_TYPE	ChanType	Data type (1-bit, 2-bit, ... BYTE, WORD, DWORD), see enum "DIAG_CHANPROP_TYPE" in the file "pniousrd.h"
	PNIO_BOOL	MaintenanceReq	PNIO_TRUE: Maintenance required, else PNIO_FALSE
	PNIO_BOOL	Mainte-nanceDem	PNIO_TRUE: Maintenance demanded, else PNIO_FALSE
	PNIO_UINT16	DiagTag	User defined diag tag <> 0, must be unique at a time for one subslot
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.5.2 PNIO_diag_channel_remove

PNIO_diag_channel_remove()			Function call: Application > IO Stack, synchronous
Deletion of a diagnostic record that was downloaded with "PNIO_diag_channel_add()". The same values must be given for referencing as in the corresponding "PNIO_diag_channel_add" call. If the device is the owner in an AR for this subslot, a "Diagnostic alarm - outgoing" is sent to the IO controller automatically. The parameter AlarmState specifies, if more diagnosis entries are available for the same channel. If ChannelNum == 0x8000, the diagnosis entry is valid for the complete submodule and the value of AlarmState also is valid for the complete submodule.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT16	ChannelNum	Channel number, content, and structure; see also "ChannelNumber" in /1/
	PNIO_UINT16	ErrorNum	Error number, see also /1/
	DIAG_CHANPROP_DIR	ChanDir	Data direction (IN/OUT/INOUT), see enum "DIAG_CHANPROP_DIR" in the file "pniousrd.h"
	DIAG_CHANPROP_TYPE	ChanTyp	Data type (1-bit, 2-bit, ... BYTE, WORD, DWORD), see enum "DIAG_CHANPROP_TYPE" in the file "pniousrd.h"
	PNIO_UINT16	DiagTag	Diag tag that has been specified at the appropriate call of PNIO_diag_channel_add
	PNIO_UINT16	AlarmState	DIAG_CHANPROP_SPEC_ERR_DISAPP, DIAG_CHANPROP_SPEC_ERR_DISAPP_MORE, if more diagnosis entries are available.
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.5.3 PNIO_ext_diag_channel_add

PNIO_ext_diag_channel_add()			**Function call: Application > IO Stack, synchronous**
Downloads an extended diagnostic record into a subslot. If the device is the owner of this subslot in an AR, an extended "Diagnostic alarm - incoming" is automatically sent to the IO controller. The diagnostic record can be removed with the "PNIO_ext_channel_remove()" function once the problem is rectified. The value DiagTag is a user defined value <> 0, that distinguishes different alarms for one subslot, that are valid at the same time. So it must be always unique inside one subslot. If only one alarm at a time can be available, a fix value (e.g. 1) can be used. Otherwise the application has to manage the DiagTag values and has to take care, that inside this subslot the DiagTag is always unique.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.

	PNIO_UINT16	ChanNum	Channel number, content, and structure; see also "ChannelNumber" in /1/
	PNIO_UINT16	ErrorNum	Error number, see also /1/
	DIAG_CHANPROP_DIR	ChanDir	Data direction (IN/OUT/INOUT), see enum "DIAG_CHANPROP_DIR" in the file "pniousrd.h"
	DIAG_CHANPROP_TYPE	ChanTyp	Data type (1-bit, 2-bit, ... BYTE, WORD, DWORD), see enum "DIAG_CHANPROP_TYPE" in the file "pniousrd.h"
	PNIO_UINT16	ExtChannelErrType	Extended channel error type, content and structure; see also "ExtChannelErrorType" in /1/
	PNIO_UINT32	ExtChannelAddValue	Additional value, content, and structure; see also "ExtChannelAddValue" in /1/
	PNIO_BOOL	MaintenanceReg	PNIO_TRUE: Maintenance required, else PNIO_FALSE
	PNIO_BOOL	MaintenanceDem	PNIO_TRUE: Maintenance demanded, else PNIO_FALSE
	PNIO_UINT16	DiagTag	User defined diag tag <> 0, must be unique at a time for one subslot
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.5.4 PNIO_ext_diag_channel_remove

PNIO_ext_diag_channel_remove()			**Function call: Application > IO Stack, synchronous**
Deletion of a diagnostic record that was downloaded with "PNIO_ext_diag_channel_add()". If the device is the owner in an AR for this subslot, an extended "Diagnostic alarm - outgoing" is sent to the IO controller automatically. The parameter AlarmState specifies, if more diagnosis entries are available for the same channel. If ChannelNum == 0x8000, the diagnosis entry is valid for the complete submodule and the value of AlarmState also is valid for the complete submodule.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT16	ChannelNum	Channel number, content, and structure; see also "ChannelNumber" in /1/
	PNIO_UINT16	ErrorNum	Error number, see also /1/
	DIAG_CHANPROP_DIR	ChanDir	Data direction (IN/OUT/INOUT), see enum "DIAG_CHANPROP_DIR" in the file "pniousrd.h"
	DIAG_CHANPROP_TYPE	ChanTyp	Data type (1-bit, 2-bit, ... BYTE, WORD, DWORD), see enum "DIAG_CHANPROP_TYPE" in the file "pniousrd.h"
	PNIO_UINT16	ExtChannelErrType	Extended channel error type, content and structure; see also "ExtChannelErrorType" in /1/
	PNIO_UINT32	ExtChannelAddValue	Additional value, content, and structure; see also "ExtChannelAddValue" in /1/
	PNIO_UINT16	DiagTag	Diag tag that has been specified at the appropriate call of PNIO_ext_diag_channel_add
	PNIO_UINT16	AlarmState	DIAG_CHANPROP_SPEC_ERR_DISAPP, DIAG_CHANPROP_SPEC_ERR_DISAPP_MORE, if more diagnosis entries are available.
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.5.5 PNIO_diag_generic_add

PNIO_diag_generic_add()			**Function call: Application > IO Stack, synchronous**
Downloads a manufacturer-specific diagnostic record into a subslot. The diagnostic data can be read out by means of a special record call (see /1/), for example, by a diagnostic tool. Multiple diagnostic records that are referenced by a user-specifiable tag can be downloaded to a subslot. The diagnostic record can be removed with the "PNIO_diag_generic_remove()" function by means of this reference. If the device is the owner in an AR for this subslot, a "manuf. specific incoming alarm" is sent to the IO controller automatically.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT16	ChannelNum	Channel number
	DIAG_CHANPROP_DIR	ChanDir	Data direction (IN/OUT/INOUT), see enum "DIAG_CHANPROP_DIR" in the file "pniousrd.h"
	DIAG_CHANPROP_TYPE	ChanTyp	Data type (1-bit, 2-bit, ... BYTE, WORD, DWORD), see enum "DIAG_CHANPROP_TYPE" in the file "pniousrd.h"
	PNIO_UINT16	DiagTag	User defined diag tag <> 0, must be unique at a time for one subslot
	PNIO_UINT16	UserStructIdent	User structure identifier; see /1/: 0..7fff: Manufacturer-specific data in "pInfoData"
	PNIO_UINT8*	pInfoData	Pointer to the diagnostic data
	PNIO_UINT32	InfoDataLen	Length of the diagnostic data in bytes
	PNIO_BOOL	MaintenanceReq	PNIO_TRUE: Maintenance required, else PNIO_FALSE
	PNIO_BOOL	Mainte-nanceDem	PNIO_TRUE: Maintenance demanded, else PNIO_FALSE
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.5.6 PNIO_diag_generic_remove

PNIO_diag_generic_remove()			**Function call: Application > IO Stack, synchronous**
Deletion of a diagnostic record that was downloaded with "PNIO_diag_generic_add()". If the device is the owner in an AR for this subslot, a "manuf. specific outgoing alarm" is sent to the IO controller automatically.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT16	ChanNum	Channel number
	DIAG_CHANPROP_DIR	ChanDir	Data direction (IN/OUT/INOUT), see enum "DIAG_CHANPROP_DIR" in the file "pniousrd.h"
	DIAG_CHANPROP_TYPE	ChanTyp	Data type (1-bit, 2-bit, ... BYTE, WORD, DWORD), see enum "DIAG_CHANPROP_TYPE" in the file "pniousrd.h"
	PNIO_UINT16	DiagTag	Diag tag that has been specified at the appropriate call of PNIO_diag_generic_add
	PNIO_UINT16	UserStructIdent	User structure identifier; see /1/: 0..7fff: Manufacturer-specific data in "pInfoData"
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.6 Sending and receiving alarms

The following subslot-specific alarms can be triggered by means of the IOD API:

- Process alarms (optional)
- Status alarms (optional)
- Diagnostic alarms (optional)
- "Return of submodule" alarms (mandatory)

Process, status and diagnostic alarms can be triggered by the application if it has detected a relevant event. Process and status alarms are thereby initiated directly by the application; however, diagnostic alarms are triggered automatically by the PROFINET stack when a diagnostic entry is made by the application. "Return of submodule" alarms must be triggered by the application if the user-data accompanying elements (IOPS, IOCS) change from "BAD" to "GOOD" during operation.

Implementation of the alarm functions is **asynchronous**, which means the function does not wait for the alarm to be acknowledged by the IO controller. Instead, after receipt of the alarm acknowledgment, the IO stack calls the "PNIO_cbf_async_req_done()" callback function which must be implemented by the user.

4.1.6.1 PNIO_process_alarm_send

PNIO_process_alarm_send()			**Function call: Application > IO Stack, asynchronous**
Sends a (submodule-specific) process alarm to an IO controller. The accompanying data are contained in the alarm frame to the IO controller, but are not stored locally in the submodule. This means a remove function is not required.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT8*	pData	Pointer to alarm data
	PNIO_UINT32	DataLen	Length of alarm data, in bytes
	PNIO_UINT16	UserStructIdent	User structure identifier; see /1/: 0..7fff: Manufacturer-specific data in "pData"
	PNIO_UINT32	UserHndl	Reserved in the current version.
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.6.2 PNIO_status_alarm_send

PNIO_status_alarm_send()			**Function call: Application > IO Stack, asynchronous**
Sends a (submodule-specific) status alarm to an IO controller. The accompanying data are contained in the alarm frame to the IO controller, but are not stored locally in the submodule. This means a remove function is not required.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT8*	pData	Pointer to alarm data
	PNIO_UINT32	DataLen	Length of alarm data, in bytes

	PNIO_UINT16	UserStructIdent	User structure identifier; see /1/: 0..7fff: Manufacturer-specific data in "pData"
	PNIO_UINT32	UserHndl	Reserved in the current version.
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.6.3 PNIO_upload_retrieval_alarm_send

PNIO_upload_retrieval_alarm_send()			**Function call: Application > IO Stack, asynchronous**
With an upload/retrieval alarm, an event is sent to a central parameter server (iPar server). This event causes the iPar server to read a set of parameters from the device by means of a record read service or to transfer a set of parameters to the device by means of a record write service. A header that is part of the alarm data stores which record index is used and whether the data is to be read or written. You will find an iPar server example code for STEP7 and TIA Portal on the customer support websites of Siemens on request.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	*pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT8*	*pData	Pointer to alarm data. The data starts with a 24-byte long header. It determines the direction of transmission, the data length and the record index used. The structure of the header is defined in the PNIO specification. A user example is included in the application code, see "usriod_main.c" file, "UploadAlarmDate[]" and "RetrievalAlarmData[]" data structures.
	PNIO_UINT32	DataLen	Length of alarm data, in bytes.
	PNIO_UINT32	UserHndl	Reserved in the current version.
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.6.4 PNIO_ret_of_sub_alarm_send

PNIO_ret_of_sub_alarm_send()			**Function call: Application > IO Stack, asynchronous**
Sends a "Return of submodule" alarm to the IO controller. The alarm must be issued by the device if the status of the user data-accompanying IOPS/IOCS changes from "BAD" to "GOOD" status. The response on the IO controller is similar to the response in the event of a plug alarm; however, the submodule does not have its parameters reassigned by the IO controller in the case of "PNIO_ret_of_sub_alarm_send()". **Note**: If, on the other hand, IOPS/IOCS changes from "GOOD" to "BAD", no alarm must be triggered.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	API number (default API is 0)
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT32	UserHndl	Reserved in the current version
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.6.5 PNIO_cbf_dev_alarm_ind()

PNIO_cbf_dev_alarm_ind()			**Function call: IO stack > Application, synchronous**
With this function, the application is notified of an alarm that has been received by the IO controller. **Note**: Not implemented; currently the controller does not send alarms to the device that are passed on to the application).			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_DEV_ALARM_DATA*	pAlarm	Pointer to alarm data of type "PNIO_DEV_ALARM_DATA". Other information about the alarm are supplied in these data.
Output	-	-	-

4.1.7 Acknowledgment of asynchronous functions

4.1.7.1 PNIO_cbf_async_req_done

PNIO_cbf_async_req_done()			**Function call: IO stack > Application, synchronous**
If an asynchronous request was issued to the stack by the application, the acknowledgement takes place by calling the "PNIO_cbf_async_req_done" function. In addition to the status (OK/not OK), a UserHandle, which has been assigned by the application, is transferred as a transfer parameter. This enables the application to assign the acknowledgement to the corresponding request if multiple requests were issued to the IO stack in parallel. If the appropriate submodule, the alarm has been assigned to, is not included in a running application relation (AR), then ArNum = 0 is returned (dummy-acknowledgement, to simplify handling in application). Presently, only the alarms are implemented as asynchronous requests.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	ArNum	AR numbers (1 to N), 0: no AR available for this subslot
	PNIO_ALARM_TYPE	AlarmType	Alarm type (PNIO_ALM_CHAN_DIAG, PNIO_ALM_EXT_CHAN_DIAG, ...), see enum "PNIO_ALARM_TYPE" in the file "pniousrd.h"
	PNIO_UINT32	Api	API number (Application Process Identifier)
	PNIO_DEV_ADDR*	pAddr	Slot/subslot
	PNIO_UINT32	Status	"PNIO_OK" "PNIO_NOT_OK"
	PNIO_UINT16	DiagTag	DiagTag, returned as a reference to the appropriate diag-add function for channel-diagnosis, ext-channel-diagnosis and generic-diagnosis. Otherwise “don’t care”.
Output	-	-	

4.1.7.2 PNIO_trigger_pndv_ds_rw_done()

PNIO_trigger_pndv_ds_rw_done()			**Function call: Application > IO Stack, synchronous**
Triggering of stack from HOST controller in case of asynchronous requests			
Input	PNIO_ERR_STAT*	PnioStat	Result
	PNIO_UINT32	bufLen	Length of data
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.8 Reading and writing records

In addition to the synchronous handling (which means complete handling of a read/write record request inside the callback function "PNIO_cbf_rec_read()" or "PNIO_cbf_rec_write()"), an asynchronous handling of read or write record requests is also possible. In this case, the application notifies the stack inside the callback function that the response will be delayed, which means it is executed asynchronously.

The scenario for a **synchronous read record request** is as follows:

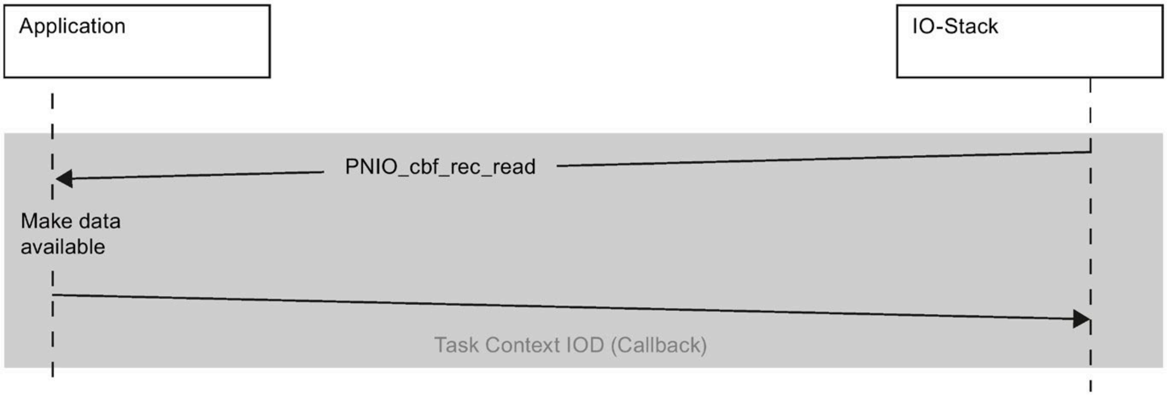


Figure 4-1 Synchronous read record handling

- A read record request from the IO controller is received and evaluated by the IO stack.
- The IO stack calls "PNIO_cbf_rec_read".
- The application provides the requested record data and error state inside the callback function and writes them to the addresses specified by the IO stack.
- After returning from the callback function, the request is completed from the point of view of the application.

The scenario for an **asynchronous read record request** is as follows:

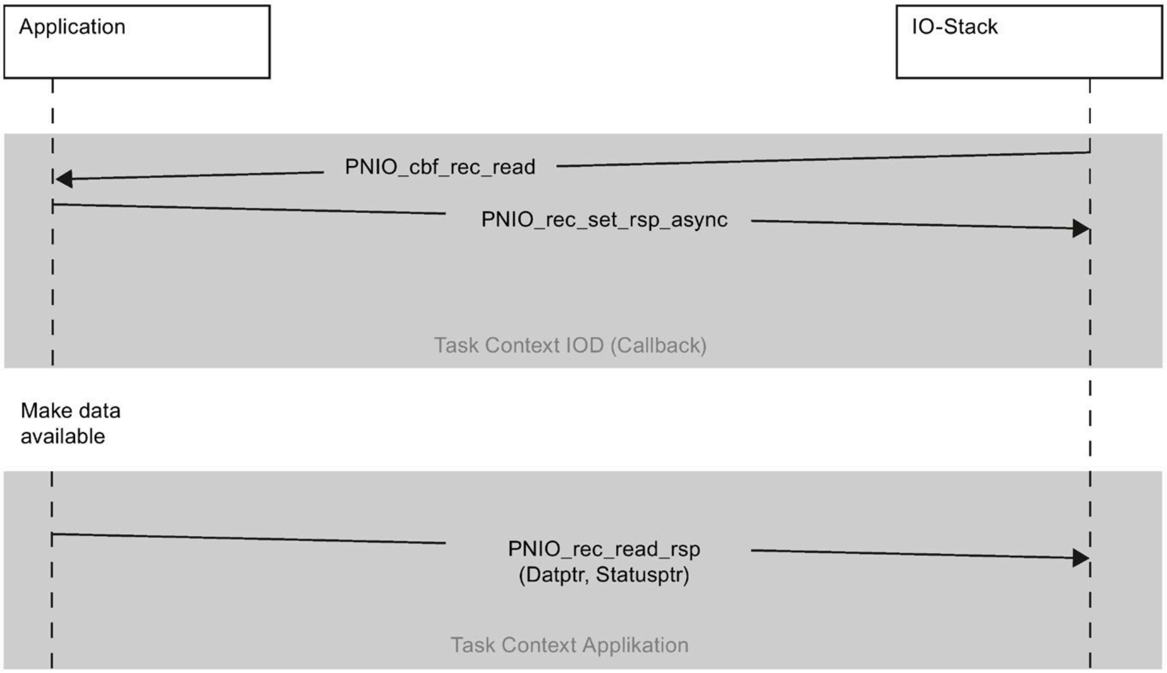


Figure 4-2 Asynchronous read record handling

- A read record request from the IO controller is received and evaluated by the IO stack.
- The IO stack calls "PNIO_cbf_rec_read()".
- The application calls "PNIO_rec_set_rsp_async()" from inside the callback function, and thereby notifies the stack that the request will be processed asynchronously and need not be (but can be) finished within the callback function. As a return value, a request handle is transferred to the application to reference this request during subsequent transfer of the data to the stack. The addresses specified by the IO stack for record data and the error status will be not further used by the application.
- The application provides the requested record data, the length of the data, and the error status from within any task context to any memory address.
- The application calls "PNIO_rec_read_rsp()" and in doing so transfers the record data, data length, and error status to the stack.

Synchronous and asynchronous write record requests are handled in the same way.

4.1.8.1 PNIO_cbf_rec_read

<table>
<tr><th colspan="3">PNIO_cbf_rec_read()</th><th>Function call: IO stack > Application, synchronous</th></tr>
<tr><td colspan="4">This function is called by the IO stack if the IO controller has sent a read record data request to the device. A record is addressed by means of SlotNumber - SubslotNumber - Index. The application reads the requested data from the subslot and writes it to the address specified by "pBuf". The maximum permitted data length, in bytes, is transferred from the stack in "*pBufLen"; the actual transferred byte count is likewise reported back by the application in "*pBufLen".
"PNIO_cbf_rec_read()" is called by the IO stack only for inserted submodules.</td></tr>
<tr><td>Input</td><td>PNIO_UINT32</td><td>DevHndl</td><td>Device handle created by the stack using "PNIO_device_open()".</td></tr>
<tr><td></td><td>PNIO_UINT32</td><td>Api</td><td>Application Process Identifier, specifies a profile</td></tr>
<tr><td></td><td>PNIO_UINT16</td><td>ArNum</td><td>AR number</td></tr>
</table>

	PNIO_UINT16	SessionKey	Session Key
	PNIO_UINT32	SequenceNum	Sequence number (gaps in the numbering are possible). It can be used at the application level for handling multiple quasi-simultaneous requests.
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT32	RecordIndex	Record index of the data to be read
	PNIO_UINT32*	pBufLen	(only for synchronous operation, has no use with asynchronous mode) Pointer to the quantity of record data, in bytes. Here the stack transfers the maximum permitted record data length; the application returns the actual amount that was written. **The maximum data length specified by the stack must not be exceeded under any circumstances.**
	PNIO_UINT8*	pBuffer	(only for synchronous operation, has no use with asynchronous mode) Pointer to where the application must copy the record data that has been read.
	PNIO_ERR_STAT*	pPnioState	(only for synchronous operation, has no use with asynchronous mode) Pointer to 4-byte PNIO status, contains ErrCode, ErrDecode, ErrCode1, ErrCode2, AddValue 1, AddValue 2 per IEC 61158, see /2/
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.8.2 PNIO_cbf_rec_write

PNIO_cbf_rec_write()			**Function call: IO stack > Application, synchronous**
This function is called by the IO stack if the IO controller has sent a write record data request to the device. A record is addressed by means of SlotNumber - SubslotNumber - Index. The application accepts the record data starting from the address assigned with "pBuf". The data length in bytes is passed by the stack in "*pBufLen"; the actual transferred byte count is likewise reported back by the application in "*pBufLen". "PNIO_cbf_rec_write()" is called by the IO stack only for inserted submodules.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	Api	Application Process Identifier, specifies a profile
	PNIO_UINT16	ArNum	AR number
	PNIO_UINT16	SessionKey	Session Key
	PNIO_UINT32	SequenceNum	Sequence number (gaps in the numbering are possible). It can be used at the application level for handling multiple quasi-simultaneous requests.
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT32	RecordIndex	Record index of the data to be read
	PNIO_UINT32*	pBufLen	Pointer to the quantity of record data, in bytes. Here the stack transfers the maximum permitted record data length. In synchronous mode the application returns the actual amount that was written. **The maximum data length specified by the stack must not be exceeded under any circumstances.**
	PNIO_UINT8*	pBuffer	Pointer to the record data.
	PNIO_ERR_STAT*	pPnioState	(Only for synchronous operation, has no use with asynchronous mode) Pointer to 4-byte PNIO status, contains ErrCode, ErrDecode, ErrCode1, ErrCode2, AddValue 1, AddValue 2 per IEC 61158, see /2/

Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.8.3 PNIO_rec_set_rsp_async

PNIO_rec_set_rsp_asnyc()			**Function call: Application > IO stack** **(may be called only from "PNIO_cbf_rec_read" or "PNIO_cbf_rec_write")**
With this function, called from inside the callback functions "PNIO_cbf_rec_read()" or "PNIO_cbf_rec_write()", the application signals that the provision of the data will occur asynchronously. If "PNIO_rec_set_rsp_async()" is not called, the stack assumes synchronous processing; the interface is thus compatible with older versions of the development kit.			
Input	-	-	
Output	PNIO_VOID*	return	Handle to reference the request later when data is transferred to the stack

4.1.8.4 PNIO_rec_read_rsp

PNIO_rec_read_rsp			**Function call: Application > IO stack**
In the case of asynchronous mode only, a read record request is completed using "PNIO_rec_read_rsp()". In doing so, the following is transferred to the stack: the data, the error state, and the length of the data actually read from the submodule. The function can be called from any user task.			
Input	PNIO_VOID*	pRqHnd	The handle for referencing the request was transferred to the application as a return value from the previous call of "PNIO_rec_set_rsp_async()".
	PNIO_UINT8*	pDat	Pointer to the data provided by the application. In asynchronous mode the memory for the record data is provided by the application, and not (as in synchronous mode) by the IO stack.
	PNIO_UINT32	NettoDatLength	Length of the record data that was actually read from the submodule
	PNIO_ERR_STAT*	pPnioState	Pointer to the data provided; consists of 4-byte PNIO status (contains ErrCode, ErrDecode, ErrCode1, ErrCode2) as well as 2 bytes each for AddValue 1 and AddValue 2 according to IEC 61158, see /2/. In asynchronous mode the memory for the error status data is provided by the application and not (as in synchronous mode) by the IO stack.
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.8.5 PNIO_rec_write_rsp

PNIO_rec_write_rsp			**Function call: Application > IO stack**
In the case of asynchronous mode, a write record request is completed using "PNIO_rec_write_rsp()". In doing so, the following is transferred to the stack: the error status and the length of the data actually written to the submodule. The function can be called from any user task.			
Input	PNIO_VOID*	pRqHnd	The handle for referencing the request was transferred to the application as a return value from the previous call of "PNIO_rec_set_rsp_async()".
	PNIO_UINT32	NettoDatLength	Length of the record data that was actually written to the submodule

PNIO_rec_write_rsp			**Function call: Application > IO stack**
	PNIO_ERR_STAT*	pPnioState	Pointer to the data provided; consists of 4-byte PNIO status (contains ErrCode, ErrDecode, ErrCode1, ErrCode2) as well as 2 bytes each for AddValue 1 and AddValue 2 according to IEC 61158, see */2/*. In asynchronous mode the memory for the error status data is provided by the application and not (as in synchronous mode) by the IO stack.
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.8.6 PNIO_cbf_substval_out_read

PNIO_cbf_substval_out_read			**Function call: IO stack -> Application**
In order to independently process a read record request to index 0x8028 (read input data) and 0x8029 (read output data) in the PNIO stack, the stack of the application requires the substitute values set for the outputs for this. These are fetched from the stack by the application using PNIO_cbf_substval_out_read. **Note:** Optionally, the handling of the above-mentioned records can be shifted completely to the application. For this, #define INCLUDE_REC8028_8029_HANDLING 0 must be set in the iod_cfg2.h file. PNIO_cbf_substval_out_read is then no longer called. Instead, record read requests (index 0x8028, 0x8029) are passed to the application for processing using PNIO_rec_read().			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_DEV_ADDR*	pAddr	Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.
	PNIO_UINT32	BufLen	Length of substitute value data in bytes.
	PNIO_UINT8*	pBuffer	Pointer to the data buffer into which the application must copy the substitute values. **The data length specified in "DataLen" must not be exceeded under any circumstances.**
	PNIO_UINT16*	pSubstMode	Pointer to substitution mode; this is pre-assigned by the stack and can be changed by the application: 0: ZERO, 0 is returned as the substitute value (default) 1: LastValue: The last valid values received by the IOC are output as substitute values 2: Replacement : The substitute values stored under pBuffer are output.
	PNIO_UINT16*	pSubstActive	This value is pre-assigned by the stack and can be changed by the application: 0 = Normal operation (default used if IOPS and IOCS = GOOD). 1 = Substitute value output active
Output	PNIO_IOXS	Iops	Status value for the substitute values. The application should enter GOOD as a return value here.

4.1.8.7 PNIO_cbf_data_read_IOxS_only()

PNIO_cbf_data_read_IOxS_only()			**Function call: IO stack > Application, synchronous**
Update only IOxS for read			
Input	PNIO_UINT32	DevHndl	Device handle
	PNIO_DEV_ADDR *	pAddr	Geographical or logical address
	PNIO_IOXS	Iops	Remote provider status
Output	PNIO_IOXS	return	consumer state (of local io device)

4.1.8.8 PNIO_cbf_data_write_IOxS_only()

PNIO_cbf_data_write_IOxS_only()			**Function call: IO stack > Application, synchronous**
Update only IOxS for write			
Input	PNIO_UINT32	DevHndl	Device handle
	PNIO_DEV_ADDR *	pAddr	Geographical or logical address
	PNIO_IOXS	Iops	Remote provider status
Output	PNIO_UINT32	return	Return local provider state

4.1.9 Cyclic data exchange using standard interface (SI)

4.1.9.1 PNIO_initiate_data_read, PNIO_initiate_data_write

PNIO_initiate_data_read()			**Function call: Application > IO Stack, synchronous**
This function performs one-time exchange of IO output data (data transfer direction: IO controller > device) between the IO stack and the application for all ARs (RT, IRT). The PN stack reserves a data buffer. The IO stack then calls the "PNIO_cbf_data_read()" function for all submodules with output data for which an active IO-AR to an IO controller exists. The application is therein requested to read the relevant IO output data from the IO stack and write it to the outputs of the submodule. The IO consumer status and IO provider status are also exchanged. "PNIO_initiate_data_read()" behaves synchronously, which means "PNIO_initiate_data_read()" does not return until after all "PNIO_cbf_data_read()" calls are called. The updated IO data are sent to the IO controller with the next transfer cycle. The user does not have to be concerned about buffer handling; the PN stack takes care of this. The user only has to implement the "PNIO_cbf_data_read()" function. **A function body for this is located in the "iodapi_event.c" module.**. Data consistency is ensured by locking mechanisms (max. 254 bytes consistent).			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

PNIO_initiate_data_write()			**Function call: Application > IO Stack, synchronous**
This function performs one-time exchange of IO input data (data transfer direction: device > IO controller) between the IO stack and the application for all ARs (RT, IRT). The PN stack initially reserves a data buffer. The IO stack the calls the "PNIO_cbf_data_write()" function for all submodules with input data for which an active IO-AR to an IO controller exists. The application is therein requested to read the relevant IO input data from the submodule and write it to the buffer assigned by the IO stack. The IO consumer status and IO provider status are also exchanged. "PNIO_initiate_data_write()" behaves synchronously, which means "PNIO_initiate_data_write()" does not return until after all "PNIO_cbf_data_write()" calls are called. The user does not have to be concerned about buffer handling; the PN stack takes care of this. The user only has to implement the "PNIO_cbf_data_write()" function. **A function body for this is located in the "iodapi_event.c" module.**. Data consistency is ensured by locking mechanisms (max. 254 bytes consistent).			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.9.2 PNIO_cbf_data_write, PNIO_cbf_data_read

<table>
<tr><th colspan="3">PNIO_cbf_data_write()</th><th>Function call: IO stack > Application, synchronous</th></tr>
<tr><td colspan="4">Reads in the physical input data from the submodule and writes it to the buffer specified by the IO stack. The function is called by the IO stack after the application has initiated a data communication with "PNIO_initiate_data_write()".
The application must read the physical inputs of the submodule inserted in the slot/subslot and copy them to the buffer address specified by the stack.
<b>Caution: The length specified with "DataLen" must not be exceeded under any circumstances. The user is responsible for ensuring this.</b></td></tr>
<tr><td>Input</td><td>PNIO_UINT32</td><td>DevHndl</td><td>Device handle created by the stack using "PNIO_device_open()".</td></tr>
<tr><td></td><td>PNIO_DEV_ADDR*</td><td>pAddr</td><td>Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.</td></tr>
<tr><td></td><td>PNIO_UINT32</td><td>BufLen</td><td>Length of data, in bytes.</td></tr>
<tr><td></td><td>PNIO_UINT8*</td><td>pBuffer</td><td>Pointer to data buffer to which the application must copy the IO input data. <b>The data length specified in "DataLen" must not be exceeded under any circumstances.</b></td></tr>
<tr><td></td><td>PNIO_IOXS</td><td>Iocs</td><td>Remote consumer status, was sent by the IO controller together with the output data. Currently defined in "iodapi.h": "PNIO_S_GOOD", "PNIO_S_BAD"; for more information see /1/ and /2/.</td></tr>
<tr><td>Output</td><td>PNIO_IOXS</td><td>Iops</td><td>IO Provider Status. Currently defined in "iodapi.h": "PNIO_S_GOOD", "PNIO_S_BAD"; for more information see /1/ and /2/.</td></tr>
</table>

<table>
<tr><th colspan="3">PNIO_cbf_data_read()</th><th>Function call: IO stack > Application, synchronous</th></tr>
<tr><td colspan="4">Writes the IO output data to the physical outputs of the submodule.
The function is called by the IO stack once the application has initiated a data communication with "PNIO_initiate_data_read()".
The application must read the output data specified in "pData" and output it to the physical outputs of the specified submodule. The consumer status is reported back to the stack in the return value of the function. This consumer status is transmitted to the IO controller in the next cyclic RT message frame and can be evaluated there.</td></tr>
<tr><td>Input</td><td>PNIO_UINT32</td><td>DevHndl</td><td>Device handle created by the stack using "PNIO_device_open()".</td></tr>
<tr><td></td><td>PNIO_DEV_ADDR*</td><td>pAddr</td><td>Pointer to the insertion address (slot/subslot) of the submodule. "PNIO_ADDR_GEO" must be entered as the type.</td></tr>
<tr><td></td><td>PNIO_UINT32</td><td>BufLen</td><td>Length of data, in bytes.</td></tr>
<tr><td></td><td>PNIO_UINT8*</td><td>pBuffer</td><td>Pointer to data buffer from which the application must read the IO output data.</td></tr>
<tr><td></td><td>PNIO_IOXS</td><td>Iops</td><td>Remote provider status, was sent by the IO controller together with the output data. Currently defined in "iodapi.h": "PNIO_S_GOOD", "PNIO_S_BAD"; for more possible values see /1/ and /2/.</td></tr>
<tr><td>Output</td><td>PNIO_IOXS</td><td>Iocs</td><td>IO Consumer Status. Currently defined in "iodapi.h": "PNIO_S_GOOD", "PNIO_S_BAD"; for more possible values see /1/ and /2/.</td></tr>
</table>

4.1.9.3 PNIO_get_last_apdu_status

PNIO_get_last_apdu_status()			**Function call: Application > IO Stack, synchronous**
If the application reads output data from the IO controller using the standard interface ("PNIO_initiate_data_read()" function), the corresponding APDU status is cached in the PN stack. This value can be read from the application using "PNIO_get_last_apdu_status()". In addition to various status bits, the APDU status also contains the cycle counter of IO data normalized to the base value of 31.25 µs. **Example**: If the cycle counter of two consecutive "PNIO_initiate_data_read ()" calls has changed by the value 64, the time interval between these IO data is 2 ms (64 x 31.25 µs = 2 ms). Since the APDU status is AR-specific, the number of the AR must be specified here as the transfer parameter.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	ArNum	Number of the AR (1...N)
Output	PNIO_UINT32	return	Value of the 4-byte long APDU status (see also PNIO specification /1b/). This contains: • Byte 0, 1: Cycle Counter (Big Endian format) • Byte 2: APDU status byte, see define PNIO_APDU_STATUSBYTE_MASK • Byte 3: Transfer status

4.1.10 Cyclic data exchange by means of the optional DBA interface

4.1.10.1 Cyclic data exchange by means of the optional DBA interface

As an alternative to the standard callback interface (SCI), IO data and provider/consumer status can also be exchanged via the Direct Buffer Access (DBA) interface. In this case, the complete IOCR data block, including IO data, IOPS and IOCS of the submodules, is provided to the application. The application extracts IO data, IOPS and IOCS for every submodule from this IOCR. An IOCR is either an input CR (device> IO controller) or output CR (IO controller > device).

The DBA interface includes the following functions:

PNIO_dbai_enter()	Disables the call of PNIO_cbf functions and the write access to internal AR management data, for example, when canceling AR
PNIO_dbai_buf_lock()	Requests an IOCR buffer (either input IOCR or output IOCR)
PNIO_dbai_buf_unlock()	Releases a previously allocated IOCR buffer after processing
PNIO_dbai_exit()	Releases the stack internal semaphore that was allocated with "PNIO_dbai_enter()"

For calling "PNIO_dbai_buf_lock()" and for extraction of the IO data and IOPS/IOCS information from the IOCR, the application needs additional data that is transferred from the stack to the application when the "PNIO_cbf_ar_ownership_ind()" callback function is called and must be saved there. They are valid until the AR is terminated again.

The following data is transferred when "PNIO_dbai_buf_lock" is called:

- Pointer to the relevant IOCR (application may read from the IOCR pointer contained in "PNIO_cbf_ar_ownership_ind()", if this is protected with "PNIO_dbai_enter()". Therefore, it need not retain a copy of this data.)
- Transfer direction of the IOCR (input/output)

The following data is required to access the submodule-specific IO data and IOPS/IOCS of an **input** IOCR (data transfer direction device > IO controller):

- Slot number, subslot number of the configured input and output submodules
- IO data location (offset, length) of the configured input submodules
- Location (offset) of the (local) IOPS of the configured input modules
- Location (offset) of the (local) IOCS of the configured output modules

The following data is required to access the submodule-specific IO data and IOPS/IOCS of an **output** IOCR (data transfer direction IO controller > device):

- Slot number, subslot number of the configured input and output submodules
- IO data location (offset, length) of the configured output submodules
- Location (offset) of the (local) IOPS of the configured output modules
- Location (offset) of the (remote) IOCS of the configured input modules

For a buffer access to an IOCR (input or output), the application must perform the following steps:

```
PNIO_dbai_enter()
Check whether the IOCR is still valid
If valid
       PNIO_dbai_buf_lock()
       Process the buffer
       PNIO_dbai_buf_unlock()
PNIO_dbai_exit()
```

Several IOCRs can also be processed between the calls for "PNIO_dbai_enter()" and "PNIO_dbai_exit()", i.e.:

```
PNIO_dbai_enter()
Check whether the IOCR is still valid
If valid
       PNIO_dbai_buf_lock(input CR)
       Process buffer for input CR
       PNIO_dbai_buf_unlock(input CR)

       PNIO_dbai_buf_lock(output CR)
       Process buffer for output CR
       PNIO_dbai_buf_unlock(output CR)
PNIO_dbai_exit()
```

4.1.10.2 PNIO_dbai_enter

PNIO_dbai_enter()			**Function call: Application > IO Stack, synchronous**
This function must be called before "PNIO_dbai_buf_lock()", both to lock the calling of "PNIO_cbf_xxx" callback functions and to lock the modification of AR management data by the stack. This is necessary so that these data is not deleted due to a sudden termination of the AR while the application is still accessing them. By using this lock mechanism, the application can read directly from the pointers that are transferred with the AR Info indication which remain valid until the termination of the AR.			
Input	-	-	-
Output	-	-	-

4.1.10.3 PNIO_dbai_exit

PNIO_dbai_exit()			**Function call: Application > IO Stack, synchronous**
Releases the PNIO stack resources that were locked with "PNIO_dbai_enter()". This function must be called after the buffer has been released again with "dbai_buf_unlock()". **Note**: No "PNIO_cbf_xxx()" callback functions are called by the stack between "PNIO_dbai_enter" and "PNIO_dbai_exit". The buffer processing by the application should therefore be as brief as possible.			
Input	-	-	-
Output	-	-	-

4.1.10.4 PNIO_dbai_buf_lock

PNIO_dbai_buf_lock()			**Function call: Application > IO Stack, synchronous**
Requests an IOCR buffer from the PNIO stack. This buffer contains the current IO data, IOPS, and IOCS of the configured submodules. The data is transferred using a structure of type "PNIO_BUFFER_LOCK_TYPE". The application receives the input elements of this structure by means of "PNIO_cbf_ar_ownership_ind()". The pointer to the buffer and the cycle counter from the ADPU status are transferred as output parameters. This cycle counter can be used with IRT, for example, to determine the phase in which the IO data is actually transferred when the configured reduction ratio is greater than 1.			
Input	PNIO_BUFFER_LOCK_TYPE*	pLock	Pointer to structure that contains: • AR Handle • Session Key • Transfer direction ("PNIO_IOCR_TYPE_ENUM" IocrType) • Offset in the IOCR of the IO data to be locked (with length > 255 bytes, otherwise 0) • Length of the data to be locked (EB 200P: max. 254 bytes at a time) • [out] pBuf pointer to the IOCR buffer • [out] APDU status, contains the cycle counter (bits 0 to 15)
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.1.10.5 PNIO_dbai_buf_unlock

PNIO_dbai_buf_unlock()			**Function call: Application > IO Stack, synchronous**
With this function, a buffer that was requested with "PNIO_dbai_buf_lock()" is returned to the stack after processing by the application.			
Input	PNIO_BUFFER_LOCK_TYPE*	pLock	Pointer to same data from "PNIO_dbai_buf_lock"
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.1.11 Receiving events and alarms

4.1.11.1 PNIO_cbf_ar_connect_ind

PNIO_cbf_ar_connect_ind()			**Function call: IO stack > Application, synchronous**
The function signals the application that a new connection has been made to an IO controller.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	ArType	See "cm_ar_type_enum" structure, possible values are: • "CM_AR_TYPE_SINGLE" • "CM_AR_TYPE_SINGLE_RTC3" • "CM_AR_TYPE_SINGLE_SYSRED" (currently not implemented) • "CM_AR_TYPE_SUPERVISOR" (currently not implemented)
	PNIO_UINT32	ArNum	AR numbers (1 to N)
	PNIO_UINT16	SendClock	configured Sendclock of the AR
	PNIO_UINT16	RedRatioIocrIn	configured reduction ratio for all submodules of the input-CR
	PNIO_UINT16	RedRatioIocrOut	configured reduction ratio for all submodules of the output-CR
Output	-	-	-

4.1.11.2 PNIO_cbf_ar_ownership_ind

PNIO_cbf_ar_ownership_ind()			**Function call: IO stack > Application, synchronous**
This function is used to inform the application of the specified configuration of the modules/submodules in the configuration. A data structure of type "PNIO_EXP" is passed for this. It contains a list of all configured submodules. The following is listed for each submodule: The slot (API/slot/subslot), the module and submodule ID, the IO properties (in, out, in-out) as well as the offsets for the input or output data of the submodule, and their provider and consumer states. **Assumption of the ownership** The submodules of the target configuration must be assigned before the data exchange with the AR, otherwise no valid data can be exchanged with this submodule via the AR. If the device application should NOT assume the AR ownership for a submodule (i.e. no valid IO data for this submodule should be exchanged), the OwnSessionKey element must be set to 0. Otherwise, which means when the application wants to exchange valid data for this submodule, OwnSessionKey must remain unchanged. Each subslot can be assigned a maximum of one AR, which means only one AR can assume ownership for a subslot when there are several ARs. For more ARs, this submodule is then marked as "superordinated locked". **Verification of the target/actual configuration by application** The application must also verify that the target configuration matches the actual configuration. If a wrong submodule is plugged into a slot/subslot (which means an incompatible submodule that therefore cannot be part of the data exchange), the element "IsWrongSubmod" = "PNIO_TRUE" must be set in the "PNIO_EXP_SUB" structure. If the correct submodule or a compatible replacement module has been plugged, however, the value of "IsWrongSubmod" remains unchanged (the default setting is "PNIO_FALSE").			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	ArNum	AR numbers (1 to N)
	PNIO_EXP*	pOwnSub	Pointer to data structure that contains a list of all configured submodules and their properties (slot, data type, module/submodule ID, offsets of data and IOXS in the IOCR)
Output	PNIO_VOID	pOwnSub -> Sub[i]. OwnSessionKey	Session key unchanged: Ownership for submodule is assumed SessionKey = 0: Ownership declined
	PNIO_VOID	pOwnSub -> Sub[i]. IsWrongSubmod	= PNIO_TRUE when an incompatible submodule has been plugged, and therefore no data exchange is possible Leave unchanged (PNIO_FALSE) when the correct module (identical module/submodule ID) or a compatible replacement module has been plugged so that data exchange is possible.

4.1.11.3 PNIO_cbf_ar_indata_ind

PNIO_cbf_ar_indata_ind()			**Function call: IO stack > Application, synchronous**
By means of an "AR-InData" indication, the stack notifies the application that the cyclic data communication was started, which means a first IO data frame was received from the IO controller after ApplicationReady.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT16	ArNum	Specifies the AR number (1...N), see also "PNIO_cbf_ar_connect_ind()" and "PNIO_cbf_ar_ownership_ind()".
	PNIO_UINT16	SessionKey	Session Key
Output	-	-	-

4.1.11.4 PNIO_cbf_ar_disconn_ind

PNIO_cbf_ar_disconn_ind()			**Function call: IO stack > Application, synchronous**
The stack notifies the application that a Disconnect event has occurred. A Disconnect event occurs if an existing connection is alarmed or explicitly terminated by the IO controller or device.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT16	ArNum	Specifies the AR number (1...N), see also "PNIO_cbf_ar_connect_ind()" and "PNIO_cbf_ar_ownership_ind()".
	PNIO_UINT16	SessionKey	Session Key
	PNIO_AR_REASON	ReasonCode	Describes the reason for the termination of the connection; possible reason codes for a termination are located in the "iodapi.h" file, in the enum type definition "PNIO_AR_REASON{..}".
Output	-	-	-

4.1.11.5 PNIO_cbf_param_end_ind

PNIO_cbf_param_end_ind()			**Function call: IO stack > Application, synchronous**
The stack notifies the application that the parameter assignment of all modules has been completed. The application acknowledges this function by returning "PNIO_TRUE". This causes the "ApplicationReady" message to be automatically transmitted from the stack to the IO controller. In this case, "PNIO_async_appl_rdy()" may **not** be called by the application. However, if the application is not yet ready at this time, it can acknowledge with a return value of "PNIO_FALSE". It must then call the "PNIO_async_appl_rdy()" function itself at a later time. **"PNIO_async_appl_rdy()" may and must only be called for the submodules for which the "PNIO_cbf_param_end_ind()" function has been completed with the return value "PNIO_SUBMOD_STATE_APPL_RDY_FOLLOWS".**			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT16	ArNum	Specifies the AR number (1...N), see also "PNIO_cbf_ar_connect_ind()" and "PNIO_cbf_ar_ownership_ind()".
	PNIO_UINT16	SessionKey	Session Key
	PNIO_UINT32	Api	API number (only valid, when SubslotNum is not equal to 0)
	PNIO_UINT16	SlotNum	Slot number (only valid, when SubslotNum is not equal to 0)
	PNIO_UINT16	SubslotNum	• == 0: ParamEnd for all modules, • <> 0: ParamEnd only for the specified module
	PNIO_BOOL	MoreFollows	• "PNIO_TRUE": More "PNIO_cbf_param_end_ind()" calls for additional subslots follow • "PNIO_FALSE": This is the last of all "PNIO_cbf_param_end_ind()" calls
Output	PNIO_SUBMOD_STATE	return	• "PNIO_SUBMOD_STATE_RUN", if the submodule can supply valid data • "PNIO_SUBMOD_STATE_STOP", if the submodule cannot supply valid data • "PNIO_SUBMOD_STATE_APPL_RDY_FOLLOWS" if the submodule startup is not yet complete and this information is passed later to the stack by "PNIO_async_appl_rdy()".

4.1.11.6 PNIO_cbf_ready_for_input_update_ind

<table>
<tr><th colspan="3">PNIO_cbf_ready_for_input_update_ind()</th><th>Function call: IO stack > Application, synchronous</th></tr>
<tr><td colspan="4">The stack notifies the application that valid input data must be written once to the controller after a connection is established or valid input data must be written once after plugging and re-configuring a submodule in operation before "Application Ready" is reported to the participating submodules.
For the application, this simply means that the input data must be written once to the controller (with standard interface (SI) or DBA interface) in this callback function . For example, "PNIO_initiate_data_write()" must be called for this when the SI is used.</td></tr>
<tr><td>Input</td><td>PNIO_UINT32</td><td>DevHndl</td><td>Device handle created by the stack using "PNIO_device_open()".</td></tr>
<tr><td></td><td>PNIO_UINT16</td><td>ArNum</td><td>Specifies the AR number (1...N), see also "PNIO_cbf_ar_connect_ind()" and "PNIO_cbf_ar_ownership_ind()".</td></tr>
<tr><td></td><td>PNIO_INP_UPDATE _STATE</td><td>InputUpdState</td><td>Input update status:
• "PNIO_AR_STARTUP":
First input update required after AR connection establishment
• "PNIO_AR_INDATA":
AR is already in data exchange, input update required due a subsequently plugged submodule</td></tr>
<tr><td>Output</td><td>-</td><td>-</td><td>-</td></tr>
</table>

4.1.12 Control functions

4.1.12.1 PNIO_set_dev_state

<table>
<tr><th colspan="3">PNIO_set_dev_state()</th><th>Function call: Application > IO Stack, synchronous</th></tr>
<tr><td colspan="4">Sets the state of the device to "OPERATE/CLEAR".
The function must be called once during startup to set the device to the "OPERATE" state. A subsequent reset using PNIO_DEVSTAT_CLEAR causes all IO submodules to remain in the state "superordinated locked", until another call to PNIO_set_dev_state (OPERATE) is invoked and cancels this state. An ongoing AR is terminated by each call of PNIO_set_dev_state.
<b>Note:</b> Resetting to CLEAR can signal a critical device error, causing valid IO data no longer to be processed. However, we recommend that you first check the use of submodule-specific method (i.e., set the IO status of affected submodules to BAD and generate a diagnostic entry), and only to use PNIO_set_dev_state (PNIO_DEVSTAT_CLEAR) in exceptional cases when the submodule-specific method is not suitable.</td></tr>
<tr><td>Input</td><td>PNIO_UINT32</td><td>DevHndl</td><td>Device handle created by the stack using "PNIO_device_open()".</td></tr>
<tr><td></td><td>PNIO_UINT32</td><td>DevState</td><td>New status of the device.
Possible values are
• "PNIO_DEVSTAT_OPERATE"
• "PNIO_DEVSTAT_CLEAR"</td></tr>
<tr><td>Output</td><td>PNIO_UINT32</td><td>return</td><td>• "PNIO_OK":
Request was executed without problems
• "PNIO_NOT_OK":
Error occurred during request execution</td></tr>
</table>

4.1.12.2 PNIO_device_start

PNIO_device_start()			**Function call: Application > IO Stack, synchronous**
This function activates the device for accepting a connection request from the PROFINET IO-controller. A connection can only be established after this function has been called.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
Output	PNIO_UINT32	return	• "PNIO_OK": Request was executed without problems • "PNIO_NOT_OK": Error occurred during request execution

4.1.12.3 PNIO_device_stop

PNIO_device_stop()			**Function call: Application > IO Stack, synchronous**
This function stops all running PROFINET connections. To reactivate the device, call PNIO_device_start () again.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
Output	PNIO_UINT32	return	• "PNIO_OK": Request was executed without problems • "PNIO_NOT_OK": Error occurred during request execution

4.1.12.4 PNIO_device_ar_abort

PNIO_device_ar_abort ()			**Function call: Application > IO Stack, synchronous**
This function aborts a running application relation to a PROFINET controller. As a result, the connection between the IO-controller and the IO-device is terminated.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT16	ArNum	Specifies the AR number (1...N), see also "PNIO_cbf_ar_connect_ind()" and "PNIO_cbf_ar_ownership_ind()".
Output	PNIO_UINT32	return	• "PNIO_OK": Request was executed without problems • "PNIO_NOT_OK": Error occurred during request execution

4.1.13 Hardware comparators for isochronous mode

4.1.13.1 Hardware comparators for isochronous mode

Functions have been implemented for isochronous real-time (IRT), specifically for the handling of isochronous applications. These functions can control GPIO signals or call callback functions when events occur during the IO cycle.

Such events may include:

- A predetermined delay for the start of the cycle
- IO data transfer on the bus stopped (TRANS_END)

The configuration for this is stored in the so-called ISO objects. An ISO object contains the type of the event (time stamp/TRANS_END), the required parameters, such as delay time or callback function pointer, as well as ERTEC-internal resources required for the object (timers, multiplexers, ISRs, GPIOs).

A total of six different time marks and a TRANS_END event can be defined at a given time. Depending on the configuration of the times, ISRs and GPIOs, more than seven ISO objects can be activated in total by using multiple ERTEC-internal resources. The absolute number depends on the configuration.

Sequence context of the user callback function

The callback functions of EVMA events are executed on the interrupt or system level of the operating system. They are set in the "ecos_bspadapt_ertec.c" file in the system adaptation. The functions "**Bsp_EVMA_ISR()**" and "**Bsp_EVMA_DSR()**" are implemented there for eCos. They have been installed as eCos ISR or DSR handlers for the corresponding EVMA events. When an EVMA interrupt event occurs, the operating system first calls the "Bsp_EVMA_ISR()" function. If the ISR is invoked with Return (CYC_ISR_HANDLED | CYG_ISR_CALL_DSR), "Bsp_EVMA_DSR()" is also executed. Otherwise, it is not.

The setting which determines whether the user callback function is executed in the ISR or DSR context, can be simply configured using

```
#define USER_CONTEXT_ISR          1              or
#define USER_CONTEXT_ISR          0
```

Additional changes to "Bsp_EVMA_DSR" and "Bsp_EVMA_ISR" by the user are usually unnecessary.

Note

The callback functions should be as short as possible due to the high priority class. Keep in mind the permitted conditions of the operating system when running user code in the ISR or DSR state. In the DSR state, for example, no pending operating system service calls are permitted; in the ISR state absolutely no operating system service calls are permitted.

The EVMA functions are primarily intended for isochronous IRT functions, but they can also be used in RT mode if necessary.

4.1.13.2 PNIO_IsoActivateIsrObj

PNIO_IsoActivateIsrObj()			**Function call: Application > IO Stack, synchronous**
Sets a comparator that invokes a callback function at a specified time. The point in time is a programmable delay time for the start of the cycle (NewCycle).			
Input	PNIO_VOID (PNIO_VOID*)	pIsrCbf	Callback function that is invoked at the time (NewCycle + DelayTim_ns). The execution level (ISR or DSR) can be set in the system adaptation.
	PNIO_UINT32	DelayTim_ns	Specified delay time in ns for the start of the cycle (NewCycle). Permitted values are 0 ... send clock. A reduction ratio is ignored.
	PNIO_ISO_OBJ_HNDL*	pObjHnd	The function returns a handle at the given address, which must be specified when deleting the object using "PNIO_IsoFreeObj()". If no ISO object can be created, "zero" is returned.
Output	PNIO_UINT32	return	• "PNIO_OK": Request was executed without problems • "PNIO_NOT_OK": Error occurred during request execution

4.1.13.3 PNIO_IsoActivateGpioObj

PNIO_IsoActivateGpioObj()			**Function call: Application > IO Stack, synchronous**
Sets a comparator, which outputs a pulse at a predetermined GPIO at a specified point in time. The point in time is a programmable delay time for the start of the cycle (NewCycle). The GPIO is set here to the data direction "output" in the function in addition to the corresponding alternate function (PNPLL_OUT).			
Input	PNIO_UINT32	Gpio	GPIO number on ERTEC. GPIO 0 to 7 are permitted.
	PNIO_UINT32	DelayTim_ns	Specified delay time in ns for the start of the cycle (NewCycle). Permitted values are 0 ... send clock. Any configured reduction ratio is ignored.
	PNIO_ISO_GPIO_LEVEL_TYPE	GpioLevelType	Specifies whether the output is high or low active. Permitted are "ISO_GPIO_LOW_ACTIVE", "ISO_GPIO_HIGH_ACTIVE".
	PNIO_ISO_OBJ_HNDL*	pObjHnd	The function returns a handle at the given address, which must be specified when deleting the object using "PNIO_IsoFreeObj()". If no ISO object can be created, "zero" is returned.
Output	PNIO_UINT32	return	• "PNIO_OK": Request was executed without problems • "PNIO_NOT_OK": Error occurred during request execution

4.1.13.4 PNIO_IsoActivateTransEndObj

PNIO_IsoActivateTransEndObj()			**Function call: Application > IO Stack, synchronous**
Sets a comparator that invokes a callback function after the transfer cycle has ended (TRANS_END event) on the bus. The point in time is a programmable delay time for the start of the cycle (NewCycle).			
Input	PNIO_VOID (PNIO_VOID*)	pIsrCbf	Callback function that is invoked at the time (NewCycle + Delay-Tim_ns). The execution level (ISR or DSR) can be set in the system adaptation.
	PNIO_ISO_OBJ_HNDL*	pObjHnd	The function returns a handle at the given address, which must be specified when deleting the object using "PNIO_IsoFreeObj()". If no ISO object can be created, "zero" is returned.
Output	PNIO_UINT32	return	• "PNIO_OK": Request was executed without problems • "PNIO_NOT_OK": Error occurred during request execution

4.1.13.5 PNIO_IsoFreeObj

PNIO_IsoFreeObj()			**Function call: Application > IO Stack, synchronous**
Delete a previously generated ISO object. **Note**: A GPIO configured with "PNIO_IsoActivateGpioObj()" is not reconfigured. If this GPIO is to be subsequently allocated to another function, (e.g. as GPIO input), the application must perform this switch itself using "Bsp_SetGpioMode".			
Input	PNIO_ISO_OBJ_HNDL	ObjHnd	Object handle, which was previously created by "PNIO_IsoActivatexxxxx()".
Output	PNIO_UINT32	return	• "PNIO_OK": Request was executed without problems • "PNIO_NOT_OK": Error occurred during request execution

4.1.13.6 PNIO_IsoObjCheck()

PNIO_IsoObjCheck()			**Function call: Application > IO Stack, synchronous**
Check of Iso object occupation			
Input	PNIO_ISO_OBJ_HNDL	ObjHnd	Iso object
Output	PNIO_UINT32	return	Execution status: "PNIO_OK", "PNIO_NOT_OK"

4.1.14 Error handling

4.1.14.1 PNIO_get_last_error

PNIO_get_last_error()			**Function call: Application > IO Stack, synchronous**
Reads the last error that occurred when a "PNIO_xxxx()" function was called and that was signaled by CM in the response and makes it available to the application. Because most of the functions return only an aggregate error information (OK, NOT_OK), a detailed error information can be requested here, if required. If an error occurred, it is stored and kept until a new error occurs. A function call of "PNIO_xxxxx" that completed correctly and with "PNIO_OK" does not delete the stored error value, which means "PNIO_get_last_error" should only be called if the previous request was acknowledged with an error, that is a value other than PNIO_OK.			
Input	-	-	-
Output	PNIO_ERR_ENUM	return	The possible values are stored in the enum type definition "PNIO_ERR_ENUM" in the file "pnioerrx.h": • "PNIO_OK" • "PNIO_ERR_xxxxxx"

The definition "PNIO_ERR_ENUM" is located in the file "pnioerrx.h".

4.1.14.2 PNIO_Log

PNIO_Log()			**Function call: IO stack > Application, synchronous**
With this function, the stack notifies the application that an error or logging request has taken place. The error class (fatal error, error, logging, etc.) is communicated as well as a reference to the source file (Package ID, Module ID) and the line number in the code. The application can, for example, initiate error handling depending on the error class.			
Input	PNIO_UINT32	DevHndl	Device handle created by the stack using "PNIO_device_open()".
	PNIO_UINT32	ErrLevel	Designates the error class. The logging levels are subdivided into the following levels: • "PNIO_LOG_DEACTIVATED" • "PNIO_LOG_CHAT" • "PNIO_LOG_CHAT_HIGH" • "PNIO_LOG_NOTE" • "PNIO_LOG_NOTE_HIGH" • "PNIO_LOG_WARNING" • "PNIO_LOG_WARNING_HIGH" • "PNIO_LOG_ERROR" • "PNIO_LOG_ERROR_FATAL"

PNIO_Log()			**Function call: IO stack > Application, synchronous**
	PNIO_UINT32	PackID	Designates the packet in which the error occurred. Defined values are: • "PNIO_PACKID_ACP" • "PNIO_PACKID_BSPADAPT" • "PNIO_PACKID_CLRPC" • "PNIO_PACKID_CM" • "PNIO_PACKID_DCP" • "PNIO_PACKID_EDD" • "PNIO_PACKID_GSY" • "PNIO_PACKID_LLDP" • "PNIO_PACKID_LSAS" • "PNIO_PACKID_MRP" • "PNIO_PACKID_NARE" • "PNIO_PACKID_OHA" • "PNIO_PACKID_OS" • "PNIO_PACKID_PNPB" • "PNIO_PACKID_PNDV" • "PNIO_PACKID_POF" • "PNIO_PACKID_SOCK" • "PNIO_PACKID_TSKMA" • "PNIO_PACKID_OTHERS"
	PNIO_UINT32	ModID	Together with PackID, designates the module in which the error occurred. Module ID is unique within a packet.
	PNIO_UINT32	LineNum	Number of the line in which the error occurred.
Output	-	-	-

4.1.14.3 PNIO_set_iops

PNIO_set_iops()			**Function call: Application > IO Stack, synchronous**
With this function, the application can optionally set the provider status (IOPS) for submodules that have no IO data and therefore for which an IOPS update as part of cyclic data exchange is not possible. This applies, for example, to the Ethernet interface and the Ethernet ports, which are modeled via subslot numbers >=0x8000. The set status is transferred to the controller with the next call of "PNIO_initiate_data_write" and is retained until it is overwritten by another call of "PNIO_set_iops".			
Input	PNIO_UINT32	Api	API number
	PNIO_UINT32	SlotNum	Slot number
	PNIO_UINT32	SubNum	Subslot number
	PNIO_UINT8	Iops	IOPS value to be set ("PNIO_S_GOOD", "PNIO_S_BAD")
Output	PNIO_UINT32	return	"PNIO_OK," "PNIO_NOT_OK"

4.1.15 Other functions

4.1.15.1 PNIO_printf

PNIO_printf()			**Function call: IO stack > Application, synchronous / Application > Application, synchronous**
Central substitute for a "printf()" function. To allow forwarding of the variable parameters, they are converted into a format string and an argument list of type "va_list" and then passed to the lower-level and central output function "PNIO_print()".			
Input	PNIO_INT8*	fmt	Format string, as in "printf"
	...	x, y, etc.	Variable argument list as in "printf()"
Output	-	-	-

4.1.15.2 PNIO_TrcPrintf

PNIO_TrcPrintf()			**Function call: IO stack > Application, synchronous / Application > Application, synchronous**
Central output of messages to "PNIO_print()" or to a circular buffer for later analysis as ASCII characters. To allow them to be forwarded, variable parameters are converted into format string and an argument list of type "va_list" and then passed to the lower-level and central output function. The user can analyze the circular buffer in the debugger or can export it as desired using functions to be implemented by the user (e.g., via TCP/IP or similar).			
Input	PNIO_INT8*	fmt	Format string, as in "printf"
	...	x, y, etc.	Variable argument list as in "printf()"
Output	-	-	-

4.1.15.3 PNIO_get_version

PNIO_get_version()			**Function call: Application > IO Stack, synchronous**
Read the version ID of the Development Package.			
Input	PNIO_DK_VERSION*	pVersion	Pointer to a version ID of type "PNIO_VERSION". This function copies the version to the specified address.
Output	PNIO_UINT32	return	"PNIO_OK"

4.2 Lower layer interface functions for the Board support package

4.2.1 BSP functions for all platforms

4.2.1.1 Bsp_Init

Bsp_Init()			**Function call: IO stack > BSP, synchronous**
"Init" function, called by the PNIO stack during startup before the tasks of the PNIO stack have started. The user may add any necessary initialization for the BSP adaptation interface here.			
Input	-	-	-
Output	PNIO_UINT32	return	"PNIO_OK"

4.2.1.2 Bsp_GetMacAddr

Bsp_GetMacAddr()			**Function call: IO stack > BSP, synchronous**
Reads the local device MAC address of the IO controller			
Input	PNIO_UINT8*	pDevMacAddr	Buffer for the MAC address with a length of 6 bytes. The function subsequently writes the MAC address to the designated buffer.
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.2.1.3 Bsp_GetPortMacAddr

Bsp_GetPortMacAddr()			**Function call: IO stack > BSP, synchronous**
Reads the local port MAC address of the IO controller. In addition to the device MAC address, every port must have its own port MAC address in PROFINET.			
Input	PNIO_UINT8*	pPortMacAddr	Buffer for the MAC address with a length of 6 bytes. The function subsequently writes the MAC address to the designated buffer.
	PNIO_UINT32	PortNum	Port number (1...N, N = number of ports) for which the port MAC address should be read.
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.2.1.4 Bsp_EbSetLed (implementation mandatory for DCP flashing)

Bsp_EbSetLed()			**Function call: IO stack > BSP, synchronous**
Function for toggling between various standard LEDs (if available) on the device. This makes it possible, for example, to have LEDs, for example, for Maintenance, Error, Run, DCP flashing, etc. directly controlled by the PN stack. The implementation of DCP flashing (i.e. LED = PNIO_LED_BLINK) is mandatory, the implementation of the other LEDs is optional.			
Input	PNIO_LEDTYPE	Led	Specifies the LED number, see enum "PNIO_LEDTYPE" in the file "bspadapt.h".
	PNIO_UINT32	Val	1: LED on, 0: LED off
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.2.2 Storage of non-volatile data

The following data (non-volatile data types) must be stored on a PNIO device in non-volatile memory:

- Device name
- IP suite (IP address, subnet mask, default router address)
- Records of the physical device (PDEV) that have been transferred from the PNIO controller during the connection phase.
- I&M 1 to 4 (Identification and Maintenance data, see /1/) for at least one subslot, specifically for DAP or PDEV. Optionally, additional I&M 1 to 4 records are stored for more submodules.

These NV data types are read from non-volatile memory at the next startup and transferred to the PROFINET IO stack.

The following functions are available in the PROFINET application example for this:

Bsp_nv_data_clear()	Resets all NV data types to factory setting
Bsp_nv_data_store()	Saves an NV data type to non-volatile memory
Bsp_nv_data_restore()	Reads an NV data type back from non-volatile memory
Bsp_nv_data_memfree	Releases the memory that was allocated by Bsp_nv_data_restore

The functions named above are not used by the PROFINET stack itself, but only inside the application example for the handling of non-volatile data. Users can integrate the NV data interface into their own software as an example template and then redesign it in a completely different way.

4.2.2.1 Bsp_nv_data_clear

Bsp_nv_data_clear()			**Function call: IO stack > BSP, synchronous**
This function is called from the customer application, if all non-volatile data types must be reset to the factory settings. This function may be directly called in the "PNIO_reset_factory_settings" function, for example, so that it is automatically executed when an engineering system requests a reset to factory settings. This function must be implemented by the user.			
Input	-	-	-
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.2.2.2 Bsp_nv_data_store

Bsp_nv_data_store()			**Function call: IO stack > BSP, synchronous**
This function is called by the PNIO stack (within the context of the I&M data) or by the customer application when an NV data type must be saved in non-volatile memory. This may be, for example, a device name, IP suite, or the sum of all PDEV records. The data type, the pointer to the data that is to be saved, and the length of the data that is to be saved are included. This function must be implemented by the user.			
Input	PNIO_NVDATA_TYPE	NvDataType	Specifies the NV data type; see enum "PNIO_NVDATA_TYPE"
	PNIO_VOID*	pMem	Pointer to the data that is to be saved
	PNIO_UINT32	MemSize	Length of data that is to be saved

Bsp_nv_data_store()			**Function call: IO stack > BSP, synchronous**
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.2.2.3 Bsp_nv_data_restore

Bsp_nv_data_restore()			**Function call: IO stack > BSP, synchronous**
This function is called by the PNIO stack (within the I&M data) or by the customer application during startup to read non-volatile data, such as device name, IP suite, I&M 1...4 and PDEV records, back from NV memory and then transfer them to the PNIO stack. This function always returns a valid data type. If no valid data is stored in NV memory, the factory settings are returned. This function returns a pointer to where it has copied the requested data. Because the calling program does not know the length of these data in advance (e.g., with PDEV records), the memory is allocated by "Bsp_nv_data_restore()" using "OsAlloc". After use it must be released **by the calling program** (which means by the application) using "Bsp_nv_data_memfree".			
Input	PNIO_NVDATA_TYPE	NvDataType	Specifies the NV data type; see enum "PNIO_NVDATA_TYPE"
	PNIO_VOID**	ppMem	Pointer to where the data was copied by "Bsp_nv_data_restore". Memory is automatically allocated by the stack for each call of "Bsp_nv_data_restore" and released again after use **by the calling program** using "Bsp_nv_data_memfree()".
	PNIO_UINT32*	pMemSize	Length of data that is to be saved
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.2.2.4 Bsp_nv_data_memfree

Bsp_nv_data_memfree()			**Function call: IO stack > BSP, synchronous**
This function must be called to release the data block that was received by calling "Bsp_nv_data_restore()" after it has been used. This block must **not** be released with "OsFree()".			
Input	PNIO_VOID*	pMem	Pointer to the data that was received from "Bsp_nv_data_restore"
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.2.3 Adaptation of the ERTEC switch interrupts

The switch integrated in the ERTEC 200P or ERTEC 200 has one high-priority and one low-priority interrupt, which must be connected to the PROFINET IO stack. The interrupts must be adapted to the interrupt handler through operating system functions. The stack calls the "Bsp_ErtecSwiIntConnect()" function for this.

To bind the handlers listed above to the interrupts, the stack calls the following interrupt connect function which must be implemented by the user:

Bsp_ErtecSwiIntConnect()			**Function call: IO stack > BSP, synchronous**
This function connects an interrupt handler to each high-priority and low-priority switch interrupt of the ERTEC. The function is called by the PROFINET IO stack. **The function should be left unchanged.**			
Input	PNIO_CBF_ERTEC_SWI_INT_H	pErtecSwiIntH	Address of the interrupt handler for the high-priority switch interrupt. The pointer is of the type "PNIO_CBF_ERTEC_SWI_INT_H".
	PNIO_CBF_ERTEC_SWI_INT_L	pErtecSwiIntL	Address of the interrupt handler for the low-priority switch interrupt. The pointer is of the type "PNIO_CBF_ERTEC_SWI_INT_L".

Bsp_ErtecSwiIntConnect()			**Function call: IO stack > BSP, synchronous**
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.2.4 GPIO connection

4.2.4.1 Bsp_ReadGPIOin_0_to_31

Bsp_ReadGPIOin_0_to_31()			**Function call: Application > BSP, synchronous**
Reads the values of GPIOs 0 ... 31 and makes them available in the 32-bit return value.			
Input	-	-	-
	-	-	-
Output	PNIO_UINT32	return	Values of GPIOs 0 ... 31, bit-coded (GPIO0 in bit 0, GPIO1 in bit 1, etc.).

4.2.4.2 Bsp_SetGPIOout_0_to_31

Bsp_SetGPIOout_0_to_31()			**Function call: Application > BSP, synchronous**
Sets the values of GPIOs 0 ... 31 to "1". A bit mask can be used to select which GPIOs should be set and which should remain unchanged.			
Input	PNIO_UINT32	OutMsk	Bit-coded mask for the GPIOs 0 ... 31. This specifies whether each GPIO should be set or remain unchanged. • Bit = 1: GPIO is set • Bit = 0: GPIO remains unchanged
Output	-	-	-

4.2.4.3 Bsp_ClearGPIOout_0_to_31

Bsp_ClearGPIOout_0_to_31()			**Function call: Application > BSP, synchronous**
Sets the values of GPIOs 0 ... 31 to "0". A bit mask can be used to select which GPIOs should be reset and which should remain unchanged.			
Input	PNIO_UINT32	OutMsk	Bit-coded mask for the GPIOs 0 ... 31. This specifies whether each GPIO should be reset or remain unchanged. • Bit = 1: GPIO is reset • Bit = 0: GPIO remains unchanged
Output	-	-	-

4.2.5 The generic flash interface

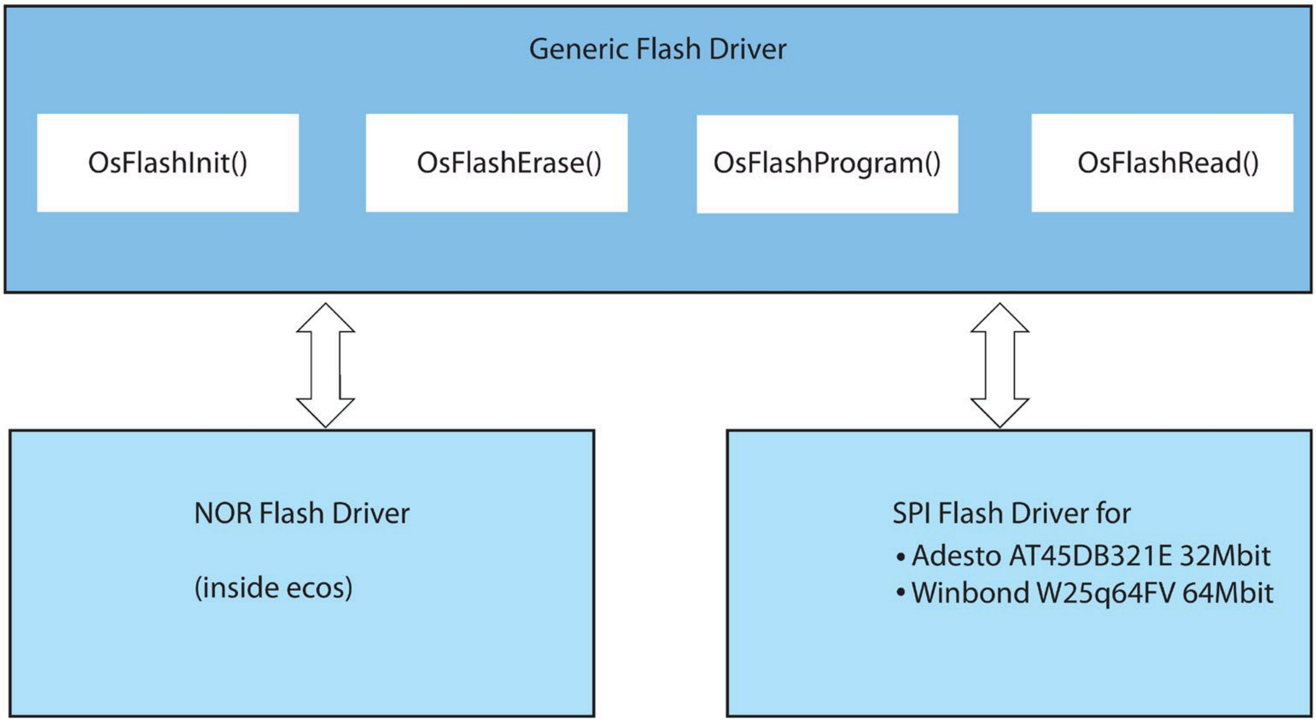
4.2.5.1 The generic flash interface

The generic flash interface provides basic software functions to erase and program a flash. On the ERTEC 200P evaluation kit these flash functions work in 2 different use cases:

- Firmware and non-volatile data are stored in NOR flash (16 or 32 bit)
- Firmware and non-volatile data are stored in an SPI flash. In this case no NOR flash is present.

On the ERTEC 200 evaluation kit these flash functions work on NOR flash only.

The following figure shows the structure of this interface:



The generic Flash driver selects automatically the correct flash. If the system has booted from SPI flash, it sets up on the SPI flash driver, otherwise on the NOR Flash driver.

4.2.5.2 OsFlashInit

OsFlashInit ()		**Function call: IO stack > BSP, synchronous**	
Initializes the generic flash driver			
Input	PNIO_UINT32	FlashSize	Size of the flash in number of bytes
Output	PNIO_UINT32	return	PNIO_OK, PNIO_NOT_OK

4.2.5.3 OsFlashErase

OsFlashErase ()			**Function call: IO stack > BSP, synchronous**
Erases a specified number of bytes inside the flash. Start address and size of the block may be any, the driver itself considers the affected flash sectors.			
Input	PNIO_UINT32	FlashStartOffset	Byte offset inside the flash, where the block to erase starts.
	PNIO_UINT32	DataSize	Size of the block to erase (number of bytes)
	PNIO_UINT32*	pError	FLASH_ERRNUM_OK (0) or error number of the lower layer driver (if available)
Output	PNIO_UINT32	return	PNIO_OK, PNIO_NOT_OK

4.2.5.4 OsFlashProgram

OsFlashProgram ()			**Function call: IO stack > BSP, synchronous**
Programs a specified number of bytes inside the flash. Start address and size of the block may be any, the driver itself considers the affected flash sectors.			
Input	PNIO_UINT32	FlashStartOffset	Byte offset inside the flash, specify the begin of the block to write
	PNIO_UINT32	pMemSrc8	Pointer to the source data, that have to be programmed into flash
	PNIO_UINT32	DataSize	Number of bytes to program
	PNIO_UINT32*	pError	FLASH_ERRNUM_OK (0) or error number of the lower layer driver (if available)
Output	PNIO_UINT32	return	PNIO_OK, PNIO_NOT_OK

4.2.5.5 OsFlashRead

OsFlashRead ()			**Function call: IO stack > BSP, synchronous**
Reads a specified number of bytes from the flash and copies them to the destination block in RAM.			
Input	PNIO_UINT32	FlashStartOffset	Byte offset inside the flash, specify the begin of the block to write
	PNIO_UINT32	pMemDst8	Pointer to the destination blockoutside the flash
	PNIO_UINT32	DataSize	Number of bytes to read
	PNIO_UINT32*	pError	FLASH_ERRNUM_OK (0) or error number of the lower layer driver (if available)
Output	PNIO_UINT32	return	PNIO_OK, PNIO_NOT_OK

4.2.6 SPI flash interface

The SPI flash driver is used by the generic Flash driver, if the system has booted from SPI flash. The SPI flash driver is usable for the following SPI flash types:

- Adesto AT45DB321E 32Mbit
- Winbond W25q64FV 64Mbit

4.2.6.1 spi_flash_init

spi_flash_init()			**Function call: Application > BSP, synchronous**
Initializes SPI and evaluates the flash type.			
Input	-	-	-
	-	-	-
Output	-	-	-

4.2.6.2 spi_flash_program

spi_flash_program ()			**Function call: Application > BSP, synchronous**
Writes data to SPI flash			
Input	unsigned int	flash_strt_addr	Destination buffer, byte offset in SPI flash
	unsigned char*	transmit_addr	Pointer to source data, that shall be written to flash
	signed int	data_size	Number of bytes to write
	unsigned int *	pError	Pointer to error return value from the lower layer flash routine (if available)
Output	int	return	0: OK, 1: Error

4.2.6.3 spi_flash_read

spi_flash_read()			**Function call: Application > BSP, synchronous**
Reads data from SPI flash			
unsigned int	flash_strt_addr	Source buffer, byte offset in SPI flash	
	unsigned char*	receive_addr	Pointer to data destination
	signed int	data_size	Number of bytes to read
	unsigned int *	pError	Pointer to error return value from the lower layer flash routine (if available)
int	return	0: Error, else number of read bytes	

4.2.6.4 spi_flash_erase

spi_flash_erase()			**Function call: Application > BSP, synchronous**
Dummy function for compatibility with firmware update process. **Note**: The SPI flash write function already cares about erasing, so there is no need for implementation.			
Input	unsigned int	flash_strt_addr	Dummy
	signed int	data_size	Dummy
	unsigned int *	pError	0
Output	int	return	0

4.2.6.5 spi_flash_chip_erase

spi_flash_chip_erase()			**Function call: Application > BSP, synchronous**
Erases the complete SPI flash			
Input	-	-	-
	-	-	-
Output	int	return	0

4.2.6.6 spi_flash_erase_verify

spi_flash_erase_erify()			**Function call: Application > BSP, synchronous**
Dummy function for compatibility with firmware update process.			
Input	unsigned int	flash_strt_addr	dummy
	signed int	data_size	dummy
Output	int	return	0

4.2.6.7 spi_flash_verify

spi_flash_verify()			**Function call: Application > BSP, synchronous**
Compares data in buffer with data in SPI flash			
Input	unsigned int	pFlash	First buffer inside SPI flash to compare, byte offset in SPI flash
	unsigned char*	pBuf	Second buffer outside SPI flash to compare, pointer to data buffer
	int	BufSize	Number of bytes to verify
Output	int	return	PNIO_OK, PNIO_NOT_OK

4.2.7 Hardware watchdog

The HW watchdog interface is implemented as set of functions, to configure enable, disable and trigger the hardware watchdog of the ERTEC 200P. Triggering the HW watchdog is in responsibility of the user application. The PROFINET stack itself does not trigger the hardware watchdog.

4.2.7.1 Bsp_hw_watchdog_init

Bsp_hw_watchdog_init()	**Function call: Application > BSP, synchronous**
Initialization of the HW watchdog and configuring the watchdog elapse time.	

Input	unsigned int	wd_time	Time factor. The formula for the watchdog elapse time is **elapse time = wd_time * wd_granity**
	BSP_WD_GRANITY	wd_granity	Time base for evaluating the watchdog elapse times. Values are *BSP_WD_100MS,* *BSP_WD_10MS,* *BSP_WD_1MS,* *BSP_WD_100US*
Output	--	--	

4.2.7.2 Bsp_hw_watchdog_start

Bsp_hw_watchdog_start()		**Function call: Application > BSP, synchronous**	
Activation of the hardware watchdog. After activation the watchdog has to be triggered cyclically by calling Bsp_hw_watchdog_trigger. If the trigger is missing for a time period greater than the configured elapse time, a hardware reset is executed.			
Input	--	--	
Output	--	--	

4.2.7.3 Bsp_hw_watchdog_stop

Bsp_hw_watchdog_stop()		**Function call: Application > BSP, synchronous**	
This function deactivates the HW watchdog, that has been activated before by calling Bsp_hw_watchdog_start.			
Input	--	--	
Output	--	--	

4.2.7.4 Bsp_hw_watchdog_trigger (void)

Bsp_hw_watchdog_()		**Function call: Application > BSP, synchronous**	
After activation of the watchdog with function Bsp_hw_watchdog_start() it has to be triggered cyclically by calling Bsp_hw_watchdog_trigger. If the trigger is missing for a time period greater than the configured elapse time, a hardware reset is executed.			
Input	--	--	
Output	--	--	

4.3 Interface to the operating system

4.3.1 Interface to the operating system

The following interface functions abstract a specific operating system interface. They must be adapted by the user to the particular operating system. In many cases, the call can be directly mapped onto an operating system call. All operating system abstraction functions are implemented in the "xxx_OS.C" module. All required interface definitions and defines for this are included in "OS.H".

4.3.2 Managing resources

The management and referencing of resources is often designed very differently in operating systems. For example, some return a pointer as a reference to a resource, such as a thread, mailbox, etc., while others return an arbitrary index. For this reason, a few indices are generated in the OS abstraction interface so that the actual operating system references are transparent to the application. The generated IDs are in a consecutive range from 0 to N such that the created ID can be used directly as a reference to the internal management block, enabling simple and fast access.

4.3.3 Description of the OS functions to be ported

4.3.3.1 OsInit()

OsInit()			**Function call: IO stack > Operating system**
This function is called once during startup of the IO stack to initialize the operating system abstraction interface. "OsInit()" must finish before any of the other "Osxxx" functions is called.			
Input	-	-	-
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.3.3.2 OsAllocFX()

OsAllocFX()			**Function call: IO stack > Operating system**
Allocation function for dynamic memory. The memory is not pre-assigned.			
Input	PNIO_VOID**	ppMem	Pointer to which the address of the allocated memory is to be written
	PNIO_UINT32	Length	Length of the memory in bytes

OsAllocFX()			**Function call: IO stack > Operating system**
	PNIO_UINT32	PoolID	Various pools can be (optionally) specified for runtime optimization. Possible defines are: • "MEMPOOL_DEFAULT" • "MEMPOOL_FAST" • "MEMPOOL_CACHED" • "MEMPOOL_UNCACHED" • "MEMPOOL_RX_TX_BUF" **Note:** All of the pools listed above may be cached in the system adaptation of the user example. "MEMPOOL_UNCACHED" and "MEMPOOL_RX_TX_BUF" are currently not used.
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.3.3.3 OsFreeX()

OsFreeX()			**Function call: IO stack > Operating system**
Releases allocated memory. Here the same pool must be specified that was used for the allocation. **Note:** The "OsFree()" function is based on "OsFreeX()" and can be used without modification.			
Input	PNIO_VOID*	pMem	Address of the allocated memory
	PNIO_UINT32	PoolID	Pool ID that was used during allocation
Output	PNIO_UINT32	return	"LSA_OK", "LSA_NOT_OK"

4.3.3.4 OsAllocTimer()

OsAllocTimer()			**Function call: IO stack > Operating system**
Assigns a timer. The timer can be configured as a cyclic timer or one-shot timer. When the timer expires, the specified callback function is called. The timer can be started with "OsStartTimer()". Upon expiration, the Timer ID and a User ID are transferred as parameters to the callback function. The User ID is specified in "OsTimerStart()".			
Input	PNIO_UINT16*	timer_id_ptr	Address as of which the Timer ID is stored as a return parameter
	PNIO_UINT16	timer_type	Timer type (cyclic timer or one-shot timer). Possible values are: • "LSA_TIMER_TYPE_ONE_SHOT" • "LSA_TIMER_TYPE_CYCLIC"
	PNIO_UINT16	timer_base	Time base for the timer. Possible values are: • "LSA_TIME_BASE_1MS" • "LSA_TIME_BASE_10MS" • "LSA_TIME_BASE_100MS" • "LSA_TIME_BASE_1S"
	PNIO_VOID*	callback_timeout	Callback function that is called when the timer expires. Transfer parameters for this are Timer ID and User ID. The Timer ID is assigned by the stack in "OsAllocTimer()"; the User ID can be selected by the user.
Output	PNIO_UINT32	return	"LSA_OK", "LSA_RET_ERR_PARAM"

4.3.3.5 OsStartTimer()

OsStartTimer()			**Function call: IO stack > Operating system**
Input	PNIO_UINT16	timer_id	Reference to the timer to be started; was generated in "OsAllocTimer()" and is a transfer parameter of the callback function that is called when the timer expires.
	PNIO_UINT32	user_id	User ID that can be assigned by the user; is likewise a transfer parameter of the callback function
	PNIO_UINT16	delay	Determines the runtime of the timer; refers to the time base specified in "OsAllocTimer()". Example: With a time base of 10 ms and a specified delay of 5, the callback function would be called after 50 ms.
Output	PNIO_UINT32	return	• "LSA_OK": OK, timer was started • "LSA_RET_ERR_PARAM": Parameter assignment error

4.3.3.6 OsStopTimer()

OsStopTimer()			**Function call: IO stack > Operating system**
Stops a running timer.			
Input	PNIO_UINT16	timer_id	Reference to the timer
Output	PNIO_UINT32	return	• "LSA_OK": OK, timer was stopped • "LSA_RET_ERR_PARAM": Parameter assignment error

4.3.3.7 OsFreeTimer()

OsFreeTimer()			**Function call: IO stack > Operating system**
Releases a timer that was allocated with "OsAllocTimer".			
Input	PNIO_UINT16	timer_id	Reference to the timer
Output	PNIO_UINT32	return	"LSA_OK", "LSA_RET_ERR_TIMER_IS_RUNNING"

4.3.3.8 OsEnterX()

OsEnterX()			**Function call: IO stack > Operating system**
Assigns a mutex. A maximum of "MAXNUM_OF_NAMED_MUTEXES" can be assigned, which are managed by "xxx_os.c".			
Input	PNIO_UINT32	MutexId	Identifier for the mutex. Possible values are: • 0.... (MAXNUM_OF_NAMED_MUTEXES - 1)
Output		-	-

4.3.3.9 OsExitX

OsExit()			**Function call: IO stack > Operating system**
Releases an assigned mutex.			
Input	PNIO_UINT32	MutexId	Identifier for the mutex. Possible values are: • 0.... (MAXNUM_OF_NAMED_MUTEXES - 1)
Output	-	-	-

4.3.3.10 OsEnterShort

OsEnterShort()			Function call: IO stack > Operating system
Note: Not used on ERTEC platforms; only for EDDS.			
Input	-	-	-
Output	-	-	-

4.3.3.11 OsExitShort

OsExitShort()			Function call: IO stack > Operating system
Note: Not used on ERTEC platforms; only for EDDS.			
Input	-	-	-
Output	-	-	-

4.3.3.12 OsAllocSemB

OsAllocSemB()			**Function call: IO stack > Operating system**
Generates a binary semaphore. The semaphore must be empty in its initial state.			
Input	PNIO_UINT32*	pSemId	Pointer as of which the semaphore ID is returned.
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.3.3.13 OsFreeSemB

OsFreeSemB()			Function call: IO stack > Operating system
Deletes a semaphore that was previously created by "OsAllocSemB()".			
Input	PNIO_UINT32	SemId	Semaphore ID that was created by "OsAllocSemB()".
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.3.3.14 OsTakeSemB

OsTakeSemB()			**Function call: IO stack > Operating system**
Occupies a binary semaphore. If the semaphore has already been occupied, the function is blocking.			
Input	PNIO_UINT32	SemId	Semaphore ID that was created by "OsAllocSemB()".
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.3.3.15 OsGiveSemB

OsGiveSemB()			**Function call: IO stack > Operating system**
Releases a semaphore that was occupied "OsTakeSemB()".			
Input	PNIO_UINT32	SemId	Semaphore ID that was created by "OsAllocSemB()".
Output	PNIO_UINT32	return	"PNIO_OK", "PNIO_NOT_OK"

4.3.3.16 OsSetThreadPrio

OsSetThreadPrio()			Function call: IO stack > Operating system
Note: Not used on ERTEC platforms; only available for DK_SW with EDDS. Changes the task priority. This causes the thread priority of the EDD low context thread to be temporarily increased in the IO stack to prevent it from being interrupted by the EDD high context thread. "OsSetThreadPrio" is used for this purpose in the output macros "EDD_ENTER_HIGH" and "EDD_EXIT_HIGH". The priority of the task is temporarily increased there to "TASK_PRIO_HIGHEST".			
Input	PNIO_UINT32	ThreadId	ID of the thread, the priority of which is to be changed.
	PNIO_UINT32	NewThreadPrio	New priority value to be set
Output	PNIO_UINT32	return	"LSA_OK", "LSA_NOT_OK"

Note

Synchronization of the EDDS High Thread and EDDS Low Thread is provided via "OsSetThreadPrio()", so that the EDDS Low Context cannot be interrupted by the EDDS High Context. The high thread, on the other hand, cannot be interrupted by the low thread because of its higher start priority.

4.3.3.17 OsCreateThread

OsCreateThread()			**Function call: IO stack > Operating system**
Creates a thread (task). All tasks run in the same address space.			
Input	PNIO_VOID*	pThreadEntry	Entry address for the task.
	PNIO_UINT8*	pThreadName	Specification of a name for the thread. This name is intended for debugging purposes only and can be omitted if the operating system does not support debugging.

OsCreateThread()		**Function call: IO stack > Operating system**	
	PNIO_UINT32	ThreadPrio	Priority of task. **Note:** The priorities of the tasks of the IO stack are set in the "os_cfg.h" file.
	PNIO_UINT32*	pThreadId	The address of the returned thread ID is specified here.
Output	PNIO_UINT32	return	"LSA_OK", "LSA_NOT_OK"

4.3.3.18 OsStartThread

OsStartThread()		Function call: IO stack > Operating system	
Starts the thread created by "OsCreateThread()". **Note:** For some operating systems, the thread is automatically started with the Create call; in others, an additional start call is required. For standardization, the model used here provides an extra start call. If, for example, the operating system starts the task automatically, the task can be held in a waiting state using a Wait flag until "OsStartThread()" is executed.			
Input	PNIO_UINT32	ThreadId	Thread ID; was transferred as a return parameter in "OsCreateThread()"
Output	PNIO_UINT32	return	"LSA_OK", "LSA_NOT_OK"

4.3.3.19 OsWaitOnEnable()

OsWaitOnEnable()		**Function call: IO stack > Operating system**	
This function enables a created task to be kept in a waiting state until an "OsStartThread()" is executed. "OsWaitOnEnable()" should thus be executed as the first call in a created task.			
Input	-	-	-
Output	PNIO_UINT32	return	"LSA_OK", "LSA_NOT_OK"

4.3.3.20 OsGetThreadId()

OsGetThreadId()		Function call: IO stack > Operating system	
Reads the Thread ID for the current task. It does not directly return the Thread ID that was provided by the operating system, but rather a reference (table index) that is generated by the OS package. For tasks that are unknown to the OS, the value of "TskIdPost" is returned. **Note:** In the context of the LSA timer, "OsGetThreadId()" can also be called by system tasks or ISRs, depending on the implementation of the OS timer functions. In such cases, no Thread ID would have been assigned by the OS, because system tasks or ISRs are certainly not created by "OsCreateThread". For users, this simply means that they have to return the Thread ID of the post thread (TskIdPost) as a dummy Thread ID.			
Input	-	-	-
Output	PNIO_UINT32	return	Thread ID of the current task. For unknown threads, which means threads that were not created by "OsCreateThread()", the value of "TskIdPost" must be returned.

4.3.3.21 OsCreateMsgQueue()

<table>
<tr><th colspan="3">OsCreateMsgQueue()</th><th>Function call: IO stack > Operating system</th></tr>
<tr><td colspan="4">Creates a message queue. Here a message queue is always retentively assigned to a thread. At most one message queue may be assigned to a thread.
Each message contains 2 pointers as data. Thus, for a pointer width of 4 bytes, a message is 8 bytes in length. The reason for this is that the "OsCreateMsgQueue" function in the system adaptation of the IO stack is frequently used to call a function in a different thread context.
<b>Example:</b> To call the "fx (pData)" function in the thread context "Thread_1", "OsSendMessageX (Thread_1, fx, pdata, OS_MBX_PRIO_NORM)" is called.</td></tr>
<tr><td>Input</td><td>PNIO_UINT32</td><td>ThreadId</td><td>ID of the thread to which the message queue is to be assigned.</td></tr>
<tr><td>Output</td><td>PNIO_UINT32</td><td>return</td><td>• "LSA_OK":
Message queue could be assigned
• "LSA_NOT_OK":
Error occurred.</td></tr>
</table>

4.3.3.22 OsWait_ms()

<table>
<tr><th colspan="3">OsWait_ms()</th><th>Function call: IO stack > Operating system</th></tr>
<tr><td colspan="4">Waits a specified time.</td></tr>
<tr><td>Input</td><td>PNIO_UINT32</td><td>PauseTime_ms</td><td>Wait time in milliseconds.</td></tr>
<tr><td>Output</td><td>-</td><td>-</td><td>-</td></tr>
</table>

4.3.3.23 OsGetTime_us()

<table>
<tr><th colspan="3">OsGetTime_us()</th><th>Function call: IO stack > Operating system</th></tr>
<tr><td colspan="4">Reads the current time, in microseconds, since the last system start.</td></tr>
<tr><td>Input</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Output</td><td>PNIO_UINT32</td><td>return</td><td>Current time in microseconds.</td></tr>
</table>

4.3.3.24 OsGetUnixTime()

<table>
<tr><th colspan="3">OsGetUnixTime()</th><th>Function call: IO stack > Operating system</th></tr>
<tr><td colspan="4">Reads the current time, in seconds. The number of seconds since the system start are indicated here.</td></tr>
<tr><td>Input</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Output</td><td>PNIO_UINT32</td><td>return</td><td>Current time in seconds.</td></tr>
</table>

4.3.3.25 OsReadMessageBlocked()

OsReadMessageBlocked()			**Function call: IO stack > Operating system**
This function performs blocked reading of a 4-byte long message for the specified thread that was sent by "OsSendMessage()". The message contains one pointer. The thread ID is required as management information to optimize performance during operation. Thus, every thread should read its Thread ID once with "OsGetThreadId()" and remember it. **Note:** As of version 3.0.0 of the development kit, the time critical communication internal to the stack has been converted from 8-byte to 4-byte messages. This was also done to set up in a time-optimized manner on operating systems that only support 4-byte messages instead of 8-byte messages.			
Input	PNIO_VOID**	ppMessage	PtrPtr to the message
	PNIO_UINT32	ThreadId	ID of the receiving thread (and thus this thread's own ID)
Output	PNIO_UINT32	return	"LSA_OK", "LSA_NOT_OK"

4.3.3.26 OsReadMessageBlockedX()

OsReadMessageBlockedX()			**Function call: IO stack > Operating system**
This function performs blocked reading of a 8-byte long message for the specified thread that was sent by "OsSendMessageX()". The message always contains 2 pointers. The thread ID is required as management information to optimize performance during operation. Thus, every thread should read its Thread ID once with "OsGetThreadId()" and remember it.			
Input	PNIO_VOID**	ppMessage1	PtrPtr to Message1
	PNIO_VOID**	ppMessage2	PtrPtr to Message2
	PNIO_UINT32	ThreadId	ID of the receiving thread (and thus this thread's own ID)
Output	PNIO_UINT32	return	"LSA_OK", "LSA_NOT_OK"

4.3.3.27 OsSendMessage()

OsSendMessage()			**Function call: IO stack > Operating system**
This function sends a message with only one pointer (instead of two). On the receiving end, the message is received with "OsReadMessageBlocked()".			
Input	PNIO_UINT32	ThreadId	ID of the receiver thread
	PNIO_VOID*	pMessage	Pointer to the actual message
	PNIO_UINT32	MsgPrio	A priority can be assigned to the message. Within the system implementation of the PNIO thread, all messages have the same priority. However, the parameter can be used in the context of adapting the IO stack to a specific platform if it is advantageous to do so.
Output	PNIO_UINT32	return	"LSA_OK", "LSA_NOT_OK"

4.3.3.28 OsSendMessageX()

OsSendMessageX()			**Function call: IO stack > Operating system**
An extended "OsSendMessage" function: Sends a message with 2 pointers. On the receiving end, the message is received with "OsReadMessageBlockedX()". This enables 2 separate messages to be transmitted with a single "OsSendMessageX()" call. For the rationale, see the description of the "OsCreateMsgQueue()" function.			
Input	PNIO_UINT32	ThreadId	ID of the receiver thread
	PNIO_VOID*	pMessage1	Pointer to actual message 1
	PNIO_VOID*	pMessage2	Pointer to actual message 2
	PNIO_UINT32	MsgPrio	A priority can be assigned to the message. Within the system implementation of the PNIO thread, all messages have the same priority. However, the parameter can be used in the context of adapting the IO stack to a specific platform if it is advantageous to do so.
Output	PNIO_UINT32	return	"LSA_OK", "LSA_NOT_OK"

4.3.3.29 __InterlockedDecrement()

__InterlockedDecrement()			**Function call: IO stack > Operating system**
Decrement a long value under interrupt lock.			
Input	PNIO_INT32	pVal	Address of the value to decrement
Output	PNIO_INT32*	pVal	The value from the specified address is decremented.
	PNIO_INT32	return	In addition, the result ("*pVal") is also sent as a return value.

4.3.3.30 __InterlockedIncrement()

__InterlockedIncrement()			**Function call: IO stack > Operating system**
Increment a long value under interrupt lock.			
Input	PNIO_INT32	pVal	Address of the value to increment
Output	PNIO_INT32*	pVal	The value from the specified address is incremented.
	PNIO_INT32	return	In addition, the result ("*pVal") is also sent as a return value.

4.3.3.31 OsIntDisable()

OsIntDisable()			**Function call: IO stack > Operating system**
Locks the interrupts of the system.			
Input	-	-	-
Output	-	-	-

4.3.3.32 OsIntEnable()

OsIntEnable()			**Function call: IO stack > Operating system**
Releases the interrupts of the system.			
Input	-	-	-
Output	-	-	-

4.3.4 Encapsulation of standard library function calls

In order to achieve the greatest possible degree of platform independence, no standard library functions are directly called in the PNIO stack. Instead, they are accessed via the OS abstraction interface. Consequently, the associated standard library header files should only be included in a few of the modules of the Development Package.

Calls of the abstraction interface are generally routed unchanged to the standard library so that a detailed description of these functions is not necessary.

The following functions of the OS interface were defined for this purpose:

- OsAtoi
- OsHtons, OsHtonl
- OsNtohs, OsNtohl
- OsMemCpy
- OsMemMove
- OsMemSet
- OsMemCmp
- OsStrCmp
- OsStrnCmp
- OsStrCpy
- OsStrnCpy
- OsStrChr
- OsStrLen
- OsRand
- OsSrand

The functions listed above can as a rule be used without modification, because they are supported in the same way by almost all platforms.

Additional functions not listed here, that are contained in "xx_OS.C", can likewise be used without modification because they do not directly access operating system functions. Thus, for example, "OsAlloc()" is redirected to "OsAllocX()" with "PoolId=DEFAULT" and does not have be adapted.

4.3.5 OS functions called by the application example

In order to achieve the greatest possible degree of platform independence, platform-specific calls by the application example were also integrated into the OS abstraction layer "xx_os.c" ("xx" stands for the platform name).

The functions described in this section are not called by the PROFINET IO stack itself, but rather only by the application example.

- "OsGetChar" reads an ASCII character from the standard console
- "OsKeyScan32" reads a 32-bit numeric value from the standard console
- "OsReboot" performs a system restart

4.4 Important notes and limitations

4.4.1 Number of IO devices

- The present implementation of the system adaptation allows only one device instance. Multidevice functionality is not implemented in the system adaptation.

4.4.2 Number of modules and submodules

- The total number of modules and submodules and the maximum values for slot and subslot numbers are defined in the "iod_cfg2.h" file in the "(...)\pn_ioddevkits\src\source\sysadapt1\cfg" subdirectory.
- Gaps are permitted in the sequence of slot numbers and subslot numbers. Thus, the full specification as defined in the value range of the PNIO slot and subslot numbers is usable whereas the maximum number of submodules is limited.

4.4.3 Maximum amount of user data for a device

- The maximum amount of process data is determined by the maximum frame size (1440 bytes net) and the number of physical subslots with input or output data (a parameter in the GSD file). The maximum data length in bytes is:
- Maximum number of input bytes = MaxInputLength - 4 - (number of input subslots) – (number of output subslots)
- Maximum number of output bytes = MaxOutputLength - 4 - (number of input subslots) – (number of output subslots)
- A submodule containing both input and output data is therefore counted as both an input subslot as well as an output subslot.
- "MaxInputLength" and "MaxOutputLength" are attributes in the GSD file. Both values should be set to 1440 bytes for ERTEC 200P (ERTEC 200: max 256 bytes), for example.

4.4.4 Functional limitations

The following functions are not included in the current version:

- Takeover of modules by a supervisor
- Multicast communication
- RT over UDP
- Shared input

POSIX system adaptation 5

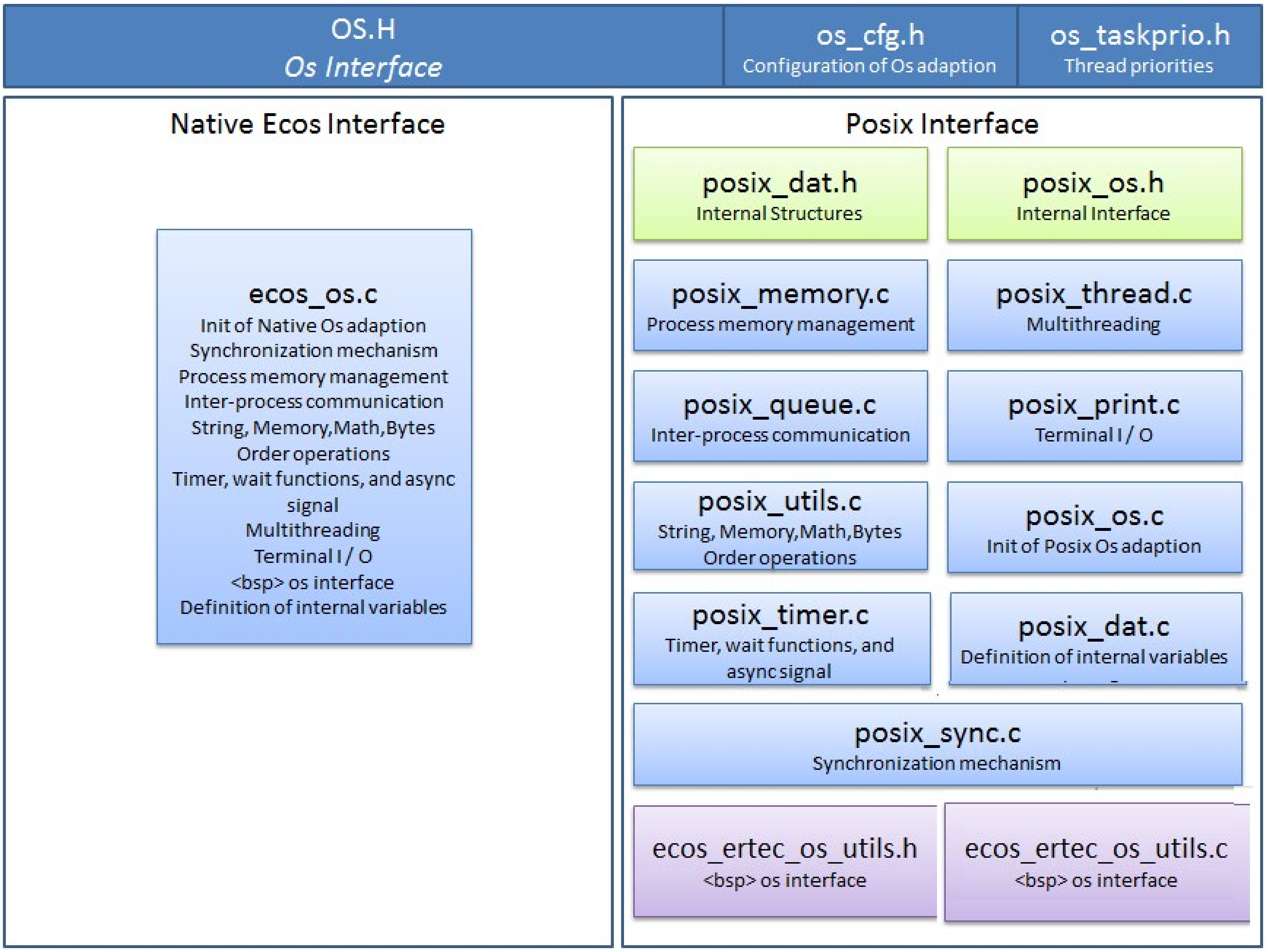

OS.H
Os Interface
os_cfg.h
Configuration of Os adaption
os_taskprio.h
Thread priorities
Native Ecos Interface
ecos_os.c
Init of Native Os adaption
Synchronization mechanism
Process memory management
Inter-process communication
String, Memory,Math,Bytes Order operations
Timer, wait functions, and async signal
Multithreading
Terminal I / O
<bsp> os interface
Definition of internal variables
Posix Interface
posix_dat.h
Internal Structures
posix_os.h
Internal Interface
posix_memory.c
Process memory management
posix_thread.c
Multithreading
posix_queue.c
Inter-process communication
posix_print.c
Terminal I / O
posix_utils.c
String, Memory,Math,Bytes Order operations
posix_os.c
Init of Posix Os adaption
posix_timer.c
Timer, wait functions, and async signal
posix_dat.c
Definition of internal variables
posix_sync.c
Synchronization mechanism
ecos_ertec_os_utils.h
<bsp> os interface
ecos_ertec_os_utils.c
<bsp> os interface

Figure 5-1 POSIX OS adaptation

The OS adaptation layer consists of 2 different adaptation solutions, which can be used **alternatively**:

- eCos native interface, which is identical to the previous versions of development kit as of V4.3.
- POSIX interface, which simplifies portability of the development kit firmware to another operating system.

The POSIX interface of the OS adaptation layer has the same functionality and the same set of functions as the eCos native interface.

5.1 POSIX adaptation files

Posix_memory.c

- Contains OS adaptation for process memory operations
- OsAllocFX, OsAllocF, OsAllocX, OsAlloc, OsFreeX, OsFree

Posix_queue.c

- Contains OS adaptation for message handling between threads
- OsMessageQueuesInit, OsMessageQueuesDestroy, OsCreateMsgQueueId, OsCreateMsgQueue, OsGetNumOfMessages, OsReadMessageBlocked, OsReadMessageBlockedX, OsSendMessage, OsSendMessageX

Posix_utils.c

- Contains OS adaptation for string, memory, endian and math operations
- OsHtonl, OsHtons, OsNtohl, OsNtohs, OsMemCpy, OsMemMove, OsMemSet, OsMemCmp, OsStrCmp, OsStrnCmp, OsStrCpy, OsStrnCpy, OsStrLen, OsStrChr, OsRand, OsSrand, OsAtoi, PNIO_log10, PNIO_pow

Posix_sync.c

- Contains OS adaptation for synchronization mechanism of threads
- OsCreateSem, OsAllocSemB, OsTakeSemB, OsGiveSemB, OsFreeSemB, OsCreateMutex, OsEnterX, OsExitX, OsEnter, OsExit, OsEnterShort, OsExitShort

Posix_print.c

- Contains OS adaptation for terminal IO handling
- PNIO_printf, PNIO_ConsoleLog, PNIO_TrcPrintf, PNIO_vsprintf, PNIO_snprintf, PNIO_sprintf, PNIO_ConsolePrintf, OsPrintTaskProp, OsKeyScan32, OsGetChar, OsStoreTraceBuffer

Posix_timer.c

- Contains OS adaptation which offers software timer’s interface and time functions
- OsAllocTimer, OsStartTimer, OsStopTimer, OsFreeTimer, OsWait_us, OsWait_ms, OsGetTime_us, OsGetTime_ms, OsGetUnixTime

Posix_thread.c

- Contains OS adaptation for thread management
- OsWaitOnEnable, OsSetMainThreadId, OsGetThreadId, OsGetThreadName, OsCreateThread, OsStartThread

Posix_os.c

- Contains initialization of POSIX OS layer adaptation
- OsInit

Posix_dat.c, Posix_dat.h

- Internal data structures of POSIX adaptation

Posix_os.h

- Declaration of internal functions which are used inside POSIX adaptation

5.2 POSIX configuration

The POSIX interface can be configured, if some header or function is not implemented in the target operating system. The implementation is already done for for the platform ecos_ertec. To add a new POSIX platform implementation, the current one with name "ecos_ertec" can be used as a template. Define a name for your platform and use this name as a prefix in the following way: The additional files <my_platform>**_os_utils.c** and <my_platform>**_os_utils.h,** which have to be present, if POSIX calls shall be used.

<my_platform>_utils.h

- The header file must be declared in compiler_stdlibs.h under the appropriate PLATFORM macro
- Using this macro supported header files are selected in POSIX interface and this macro fulfills OS function interface which are not covered within POSIX adaptation layer.

Example for using stdio.h:

/* stdio.h library is used */

#define HAVE_STDIO_H

<my_platform>_os_utils.c

Additional functions which are not part of the POSIX API, have to be implemented here.

These are:

- OsIntDisable
- OsIntEnable
- OsReboot
- OsRebootService

5.3 Integration of POSIX interface

Additional configuration settings for the POSIX interface have to be done in

- compiler.h
- compiler_stdlibs.h

compiler.h

- New platform macro for target operating system has to be added

#define PNIOD_PLATFORM_POSIX_<myplatform> 0xXXXXXXXX

- The new platform macro has to be added to derived platform definition

#define PNIOD_PLATFORM_POSIX

(PNIOD_PLATFORM_POSIX_EB200P|PNIOD_PLATFORM_POSIX_<my_platform>)

compiler_stdlibs.h

The file <my_platform>_os_utils.h has to be added here in such a way that it will be covered by preprocessor condition

```
#if (PNIOD_PLATFORM & PNIOD_PLATFORM_POSIX_<my_platform> )
 ...
 ...
 #include "<my_platform>_os_utils.h"
#endif
```

5.4 Subset of POSIX

5.4.1 Standard IO

Limitation & Recommendation

It has to support error codes which are defined in errno.h

Functions

```
#include <stdio.h>
int printf(const char *restrict format, ...);

#include <stdarg.h>
#include <stdio.h>
int vsprintf(char *restrict s, const char *restrict format, va_list ap);

#include <stdarg.h>
#include <stdio.h>
int vprintf(const char *restrict format, va_list ap);

#include <stdio.h>
int scanf(const char *restrict format, ...);

#include <stdio.h>
int getchar(void);

#include <stdarg.h>
```

```
void va_start(va_list ap, argN);

#include <stdarg.h>
void va_end(va_list ap);

#include <stdio.h>
int fflush ( FILE * stream );
```

5.4.2 Inter-process communication

Limitation & Recommendation

- It has to support error codes which are defined in errno.h
- Permissions of message queues are set to: O_RDWR | O_CREAT, S_IRUSR | S_IWUSR | S_IRGRP | S_IWGRP | S_IROTH | S_IWOTH
- Operation system has to support at least :
  - Maximum number of messages in queue : 360
  - Length of message : 4 bytes
  - Max number of message queues : 40

Functions

```
#include <mqueue.h>
mqd_t mq_open(const char *name, int oflag, ...);

#include <mqueue.h>
ssize_t mq_receive (mqd_t mqdes, char *msg_ptr, size_t msg_len, unsigned *msg_prio);

#include <mqueue.h>
int mq_send(mqd_t mqdes, const char *msg_ptr, size_t msg_len, unsigned msg_prio);

#include <mqueue.h>
int mq_close(mqd_t mqdes);

#include <mqueue.h>
int mq_unlink(const char *name);
```

```
#include <mqueue.h>
int mq_setattr(mqd_t mqdes, const struct mq_attr *restrict mqstat, struct mq_attr *restrict omqstat);
```

```
#include <mqueue.h>
int mq_getattr(mqd_t mqdes, struct mq_attr *mqstat);
```

5.4.3 Synchronization mechanisms

Limitation & Recommendation

- It has to support error codes, which are defined in errno.h
- It is necessary to use only mutexes, which are PTHREAD_MUTEX_RECURSIVE or PTHREAD_MUTEX_ERRORCHECK.
- It is necessary to use priority inheritance of mutexes set by PTHREAD_PRIO_INHERIT
- Operation system has to support at least :
  - Maximum number of semaphores : 30
  - Maximum number of mutexes : 48

Functions

```
#include <semaphore.h>
int sem_init(sem_t *sem, int pshared, unsigned value);
```

```
#include <semaphore.h>
int sem_post(sem_t *sem);
```

```
#include <semaphore.h>
int sem_wait(sem_t *sem);
```

```
#include <semaphore.h>
int sem_destroy(sem_t *sem);
```

```
#include <pthread.h>
int pthread_mutex_init(pthread_mutex_t *restrict mutex,const pthread_mutexattr_t *restrict attr);
```

```
#include <pthread.h>
int pthread_mutex_lock(pthread_mutex_t *mutex);
```

```
#include <pthread.h>
int pthread_mutex_trylock(pthread_mutex_t *mutex);
```

```
#include <pthread.h>
int pthread_mutex_unlock(pthread_mutex_t *mutex);
```

```
#include <pthread.h>
int pthread_mutex_destroy(pthread_mutex_t *mutex);
```

```
#include <pthread.h>
int pthread_mutexattr_init(pthread_mutexattr_t *attr);
```

```
#include <pthread.h>
int pthread_mutexattr_destroy(pthread_mutexattr_t *attr);
```

```
#include <pthread.h>
int pthread_mutexattr_settype(pthread_mutexattr_t *attr, int type);
```

```
#include <pthread.h>
int pthread_mutexattr_setprotocol(pthread_mutexattr_t *attr, int protocol);
```

5.4.4 Multithreading

Limitation & Recommendation

- It has to support error codes which are defined in errno.h
- Each thread is configured by PTHREAD_EXPLICIT_SCHED, in order to not inherit scheduler from parent thread.
- The scope of each thread has to be whole operation system which is defined by PTHREAD_SCOPE_SYSTEM
- Scheduler of each thread has to be set to priority round robin scheduler which is defined by SCHED_RR

- Operation system has to support at least :
- Maximum number of threads : 40

Functions

#include <pthread.h>

int pthread_create(pthread_t *restrict *thread*,const pthread_attr_t *restrict *attr*, void *(**start_routine*)(void*), void *restrict *arg*);

#include <pthread.h>

pthread_t pthread_self(void);

#include <pthread.h>

pthread_attr_init(pthread_attr_t **attr*);

#include <pthread.h>

int pthread_attr_destroy(pthread_attr_t **attr*);

#include <pthread.h>

int pthread_attr_setinheritsched(pthread_attr_t **attr*,int *inheritsched*);

#include <pthread.h>

int pthread_attr_setstackaddr(pthread_attr_t **attr*, size_t * *addr*);

#include <pthread.h>

int pthread_attr_setstacksize(pthread_attr_t **attr*, size_t *stacksize*);

#include <pthread.h>

int pthread_attr_setscope(pthread_attr_t **attr*, int *contentionscope*);

#include <pthread.h>

int pthread_attr_setschedpolicy(pthread_attr_t **attr*, int *policy*);

#include <pthread.h>

int pthread_attr_setschedparam(pthread_attr_t *restrict *attr*,const struct sched_param *restrict *param*);

5.4.5 Settings of Scheduler

Limitation & Recommendation

- It has to support error codes which are defined in errno.h
- Scheduler has to be set to priority round robin scheduler which is defined by SCHED_RR

Functions

#include <pthread.h>

int sched_get_priority_min(int *policy*);

#include <pthread.h>

int sched_get_priority_max(int *policy*);

#include <sched.h>

int sched_setscheduler(pid_t *pid*, int *policy*, const struct sched_param **param*);

5.4.6 Timers

Limitation & Recommendation

- It has to support error codes which are defined in errno.h
- It is necessary that the settings of the clock support CLOCK_REALTIME.
- Handling of timer has to be done by behavior which is done by SIGEV_SIGNAL

Functions

#include <signal.h>

#include <time.h>

int timer_create(clockid_t *clockid*, struct sigevent *restrict *evp*, timer_t *restrict *timerid*);

#include <time.h>

int timer_settime(timer_t *timerid*, int *flags*, const struct itimerspec *restrict *value*, struct itimerspec *restrict *ovalue*);

#include <time.h>

int timer_getoverrun(timer_t *timerid*);

```
#include <time.h>
int nanosleep(const struct timespec *rqtp, struct timespec *rmtp);
```

```
#include <time.h>
int clock_gettime(clockid_t clock_id, struct timespec *tp);
```

5.4.7 Process memory

Limitation & Recommendation

- It has to support error codes which are defined in errno.h

Functions

```
#include <stdlib.h>
void *malloc(size_t size);
```

```
#include <stdlib.h>
void free(void *ptr);
```

5.4.8 Asynchronous events

Limitation & Recommendation

- It has to support error codes which are defined in errno.h
- Signal SIGUSR1 has to be supported.

Functions

```
#include <signal.h>
int sigwait(const sigset_t *restrict set, int *restrict sig);
```

```
#include <signal.h>
int sigemptyset(sigset_t *set);
```

```
#include <signal.h>
```

```
int sigaddset(sigset_t *set, int signo);
```

```
#include <signal.h>
int pthread_sigmask(int how, const sigset_t *restrict set, sigset_t *restrict oset);
```

```
#include <signal.h>
int pthread_kill(pthread_t thread, int sig);
```

5.4.9 Memory operations

Limitation & Recommendation

- It has to support error codes which are defined in errno.h

Functions

```
#include <string.h>
void *memcpy(void *restrict s1, const void *restrict s2, size_t n);
```

```
#include <string.h>
void *memmove(void *s1, const void *s2, size_t n);
```

```
#include <string.h>
void *memset(void *s, int c, size_t n);
```

```
#include <string.h>
int memcmp(const void *s1, const void *s2, size_t n);
```

5.4.10 String operations

Limitation & Recommendation

- It has to support error codes which are defined in errno.h

Functions

```
#include <string.h>
```

```
int strcmp(const char *s1, const char *s2);
```

```
#include <string.h>
int strncmp(const char *s1, const char *s2, size_t n);
```

```
#include <string.h>
char *strcpy(char *restrict s1, const char *restrict s2);
```

```
#include <string.h>
char *strncpy(char *restrict s1, const char *restrict s2, size_t n);
```

```
#include <string.h>
size_t strlen(const char *);
```

```
#include <string.h>
char *strchr(const char *s, int c);
```

```
#include <string.h>
int atoi(const char *str);
```

5.4.11 Math operations

Limitation & Recommendation

- It has to support error codes which are defined in errno.h

Functions

```
#include <math.h>
double log10(double x);
```

```
#include <math.h>
double pow(double x, double y);
```

5.4.12 Byte orders operation

Limitation & Recommendation

- It has to support error codes which are defined in errno.h

Functions

#include <arpa/inet.h>

uint32_t htonl(uint32_t *hostlong*);

#include <arpa/inet.h>

uint16_t htons(uint16_t *hostshort*);

#include <arpa/inet.h>

uint32_t ntohl(uint32_t *netlong*);

#include <arpa/inet.h>

uint16_t ntohs(uint16_t *netshort*);

Appendix A

A.1 Abbreviations/Glossary of terms

ACP	**A**cyclic **C**ommunication **P**rotocol, refers to one of the basic software packages of the IO stack
AMR	**A**sset **M**anagement **R**ecord
API	**A**pplication **P**rocess **I**dentifier
AR	**A**pplication **R**elationship
BSP	**B**oard **S**upport **P**ackage
CLRPC	**C**onnection**l**ess **R**emote **P**rocedure **C**all, refers to one of the basic software packages of the IO stack
CM	**C**ontext **M**anagement, refers to one of the basic software packages of the IO stack
DAP	**D**evice **A**ccess **P**oint, specific entry in the GSD file
DBAI	**D**irect **B**uffer **A**ccess **I**nterface
DCP	**D**iscovery and basic **C**onfiguration **P**rotocol, refers to one of the basic software packages of the IO stack
DK	**D**evelopment **K**it (development kit for platforms)
DK_SW	**D**evelopment **K**it **s**oft**w**are (development kit for platforms based on standard Ethernet controllers)
DMA	**D**irect **M**emory **A**ccess
DR	**D**ynamic **R**econfiguration
eCos	**E**mbedded **C**onfigurable **O**perating **S**ystem
EK	**E**valuation **K**it (evaluation kit for platforms)
EB	**E**valuation **B**oard for ERTEC-based evaluation kits
EDD	**E**thernet **D**evice **D**river, general term for EDDI, EDDP, EDDS
EDDI	**E**thernet **D**evice **D**river for **I**RTE switch in the ERTEC 200 (earlier versions: EDD_ERTEC)
EDDP	**E**thernet **D**evice **D**river for **P**N switch in the ERTEC 200P
EDDS	**E**thernet **D**evice **D**river for **S**tandard Ethernet controller (earlier versions: EDD_soft)
ERTEC	**E**nhanced **R**eal **T**ime **E**thernet **C**ontroller
EVMA	**E**volvable **V**irtual **M**achine **A**rchitecture
GDMA	**G**eneric **D**irect **M**emory **A**ccess
GSD	**G**eneric **S**tation **D**escription
GSDML	**GSD** **M**arkup **L**anguage
GSY	**G**eneric **Sy**nc module, refers to one of the basic software packages of the IO stack
I&M	**I**dentification and **M**aintenance data
IOCR	**I**nput/**O**utput **C**ommunication **R**elationship
IOCS	**I**nput/**O**utput Object **C**onsumer **S**tatus
IOPS	**I**nput/**O**utputObject **P**rovider **S**tatus
IRT	**I**sochronous **R**eal**T**ime, Class 2 (IRT Class 2) or Class 3 (IRT Class 3)
LLDP	**L**ink **L**ayer **D**iscovery **P**rotocol (IEEE 802.1AB, allows stations to exchange chassis and port information)
LSA	**L**ayer **S**tructure **A**rchitecture
LW	Drive

MIB	**M**anagement **I**nformation **B**ase. Database for SNMP services
MRP	**M**edia **R**edundancy **P**rotocol
NARE	**N**ame **A**ddress **Re**solution
NRT	**N**on **R**eal**t**ime is a generic term for all non-real-time frames (not type 0x8892)
NV	**N**on-**v**olatile
OHA	**O**bject **Ha**ndler
OS	**O**perating **S**ystem, refers here to the abstraction layer for any operating system to which the IO stack is to be ported.
PCF	**P**olymeric **C**ladded **F**iber (optical communication medium)
PDEV	**P**hysical **Dev**ice
PI	**P**ROFIBUS/PROFINET **I**nternational, collective national organizations of the PNO
PN-IO	**P**ROFI**N**ET **IO**
PNO	**P**ROFIBUS/PROFINET **U**ser **O**rganization
POF	**P**olymeric **O**ptical **F**iber (optical communication medium)
POSIX	**P**ortable **O**perating **S**ystem **I**nterface, a family of standards (UNIX based), defined by IEEE for interface compatibility on different OS -platforms.
RT	**R**eal **T**ime is a generic term for acyclic and cyclic real-time
RT Class	**R**eal**T**ime class according to the PROFINET IO specification
SI	**S**tandard **I**nterface
SNMP	**S**imple **N**etwork **M**anagement **P**rotocol
SOCK	UDP Socket Interface for PROFINET IO, refers to one of the basic software packages of the IO stack
SPI	**S**erial **P**eripheral **I**nterface
TAP	**T**est **A**ccess **P**ort
UDP	**U**ser **D**atagram **P**rotocol
UUID	**U**niversal **U**nique **Id**entifier

A.2 References

/1a/
PROFINET IO Specification IEC 61158 – part5

PROFINET IO Application Layer Service Specification

(Can be downloaded from the PNO website (http://www.profibus.com))

/1b/
PROFINET IO Specification IEC 61158 – part6

PROFINET IO Application Layer Protocol Specification

(Can be downloaded from the PNO website (http://www.profibus.com))

/2/
GSDML Specification for PROFINET IO

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/3/
Industrial Communication with PROFINET

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Date April 2020

Article no.: 7.142