PROFIdrive

# PROFIdrive System Description

## Technology and Application

PROFIBUS • PROFINET

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# Introduction

In the dynamically developing industrial communications arena, automation is continuously evolving. Initially, automation focused exclusively on the production operation, but now it is part of a network that goes beyond the automation task itself to include service and maintenance, warehousing, resource optimization, and the provision of data for MES and ERP systems, as well as edge and cloud service. A driving force for this trend has been and continues to be fieldbus technology, which has facilitated migration from centralized to decentralized automation systems and supports the use of distributed intelligence. Ethernet-based communication systems provide a link between automation technology and information technology, thereby enabling system-wide communication from the field level up to the corporate management level.

Industrial communication systems in particular have to be capable of meeting the requirement for an integrated approach. PROFIBUS and PROFINET represent solutions that combine full integration with a high level of application orientation. With its standard protocol, PROFIBUS communication takes in all system components from machines and production and process automation to safety-related communication and drive/motion control applications, and provides the ideal basis for ensuring horizontal automation system integration. PROFINET also features a standard protocol which, in addition to horizontal communication, also supports vertical communication from the field level up to the corporate management level. Both communication systems facilitate crosssector, networked, integrated solutions that are optimized for each automation task.

The main reason why PROFIBUS and PROFINET stand out from other industrial communication systems is because they offer such an extraordinary range of applications. Not only have application-specific requirements been implemented into application profiles, but these applications have also been combined to create a standardized and open communication system. This provides the basis for ensuring outstanding investment protection for both users and manufacturers.

Drive technology represents one of the most important applications within industrial automation. According to the Federal Environment Agency, electric drives in industry and commerce consume almost two-fifths of all electricity in Germany and around 80 percent of it in these two sectors.

The tasks performed by drives and thus the requirements for the drive technology vary considerably, depending on the particular industry and/or field of application. These include:

- Drives with fixed and variable speed, such as pumps, fans, compressors, and drives for transport tasks
- Single-axis positioning controllers for applications, such as moving, adjusting and positioning
- Servo drives with central interpolation, such as those found in machine tools, robots and production machines

With such a diverse range of requirements, a technology that is flexible as well as adaptable to future requirements is needed to serve as the basis for efficient implementation into products. As a general principle, drives can be controlled very easily using the digital drive interface with all its functions. The way in which this communication connection is modeled is irrelevant when it comes to any individual drive. Existing products can be upgraded by simply transferring the device and communication models already in the drive to PROFIBUS and PROFINET. But products can only be replaced with products of the same manufacturer or the same product family. For a drive user, it is also important to be able to select from drives made by various manufacturers having an identical communication interface in order to use the optimum product for the particular application.

This is only possible with a standardized drive interface such as PROFIdrive for PROFIBUS and PROFINET. This application-oriented profile, which has been standardized in IEC 61800-7, contains standard definitions (syntax and semantics) for communication between drives and automation systems for PROFIBUS and PROFINET, thus assuring vendor neutrality, interoperability, and investment protection.

The PROFIdrive application profile represents the flexible and future-proof foundation for all drive systems in industrial automation engineering. It defines the device behavior and the process for accessing drive data of electric drives on PROFIBUS and PROFINET and also optimally integrates the additional PROFIsafe and PROFIenergy profiles.

## Notes on Content

This document describes all essential aspects of PROFIdrive technology and provides additional information on implementation and certification. Its objective is to provide a comprehensive description of the drive profile of the PROFIBUS and PROFINET communication systems without entering into too much detail.

This system description not only offers sufficient information to readers with a basic knowledge who are interested in obtaining an overview, but it also introduces experts to more extensive specialized literature. In this regard it must also be noted that, despite the care taken in preparing this document, the normative PI (PROFIBUS & PROFINET International) documents alone are authoritative and binding.

**Chapter 1** provides an introduction to how the PROFIdrive profile came about and the principles according to which it is structured.

**Chapters 2 to 6** deal with the core aspects of PROFIdrive and any repetition of the subject matter that appears in Chapter 1 is intentional for reasons of completeness.

**Chapter 7** describes how the PROFIdrive profile is mapped to PROFIBUS and PROFINET.

**Chapter 8** outlines the test procedure for obtaining a certificate.

**Chapter 9** provides guidance on how to implement the PROFIdrive interface.

**Chapter 10** briefly describes the engineering.

**Chapter 11** explains the advantages of using PROFIdrive.

**Chapter 12** concludes the document with information on the mode of action and internal structures of PI.

In the interest of ensuring clarity and because they are distributed throughout the world, official PI documents are drafted exclusively in English.

# 1. Overview

PROFIdrive is the standard profile for drive technology in conjunction with the PROFIBUS and PROFINET communication systems. The use of open "application profiles" is a tried-and-tested way of using communication systems to connect drives and controllers from different manufacturers in an interoperable and straightforward way.

The PROFIdrive profile has been specified by a working group made up of numerous device manufacturers under the PI (PROFIBUS & PROFINET International) umbrella. This working group is also responsible for continuous updates and enhancements.

Work on PROFIdrive can be traced back to 1991 when the focus was on PROFIBUS DP. The widely used profile version 2.0 appeared in 1997. In 2002, profile version 3.1 introduced the synchronous servo interface based on PROFIBUS DP-V2. In 2005, V4.0 saw the inclusion of PROFINET as a further communication system (supported by the version number 4). Also in 2005, the PROFIdrive on PROFIsafe Amendement was released, which now includes the Drive Based Safety functions from PROFIdrive. The PROFIdrive interface has been continuously developed and enhanced with new features ever since.

To satisfy the wide range of industrial automation applications for drives, PROFIdrive defines six specific and independent application classes. These reflect a detailed image of the drive performance required and enable a precisely defined selection and minimum-effort implementation of each specific drive class. The application classes can be implemented independently of each other and enable an interface optimized for the respective application or industry. Depending on the application class, the application processes are distributed optimally between the drive (e.g. current control, speed control) and controller (e.g. position control, path interpolation). The communication system is then responsible for data exchange between these distributed processes. Depending on the application class, extended communication functions are used for clock synchronization or device-to-device communication[1].

The profile has been standardized at PI and within the IEC and comprehensively documented in the relevant specification (Profile Drive Technology - PROFIdrive Profile, PI Order No. 3.172).

## 1.1. Standardization

At the initiative of the ZVEI working group "PG Antriebsschnittstelle", a project was initiated within the IEC for the purpose of specifying a standardized drive interface that could be integrated in an international standard. This resulted in the three-part IEC standard IEC 61800-7 "Generic interface and use of profiles for power drive systems".

The fact that PROFIdrive has been standardized in IEC 61800-7 and is recommended by various international institutions such as OMAC means that its future as an internationally accepted standard is guaranteed. In 2013, PROFIdrive was standardized in China as GB/T 25740.

## 1.2. Structure

The basic specifications in the PROFIdrive standard are as follows (Figure 1).

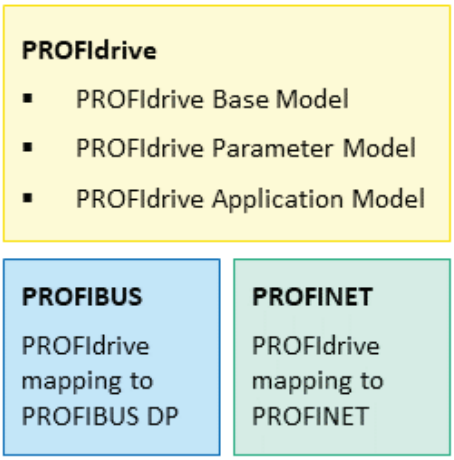


**Fig. 1: Architecture of PROFIdrive**

- Base model definition
- Parameter model definition
- Application model definition
- Mapping to PROFIBUS DP
- Mapping to PROFINET IO

The main part of the profile (yellow box in Figure 1) describes functions that are independent of the communication system and that serve to ensure that an application can be operated with PROFIBUS DP and PROFINET IO without any changes. As a result of these functions and with the use of scalable communication (from a basic fieldbus to a system-wide Ethernet network with identical application view), the drive technology can be linked without exception and without changes to the automation application.

[1] For the purposes of non-discriminatory language, the term "Device" has been chosen in this document.

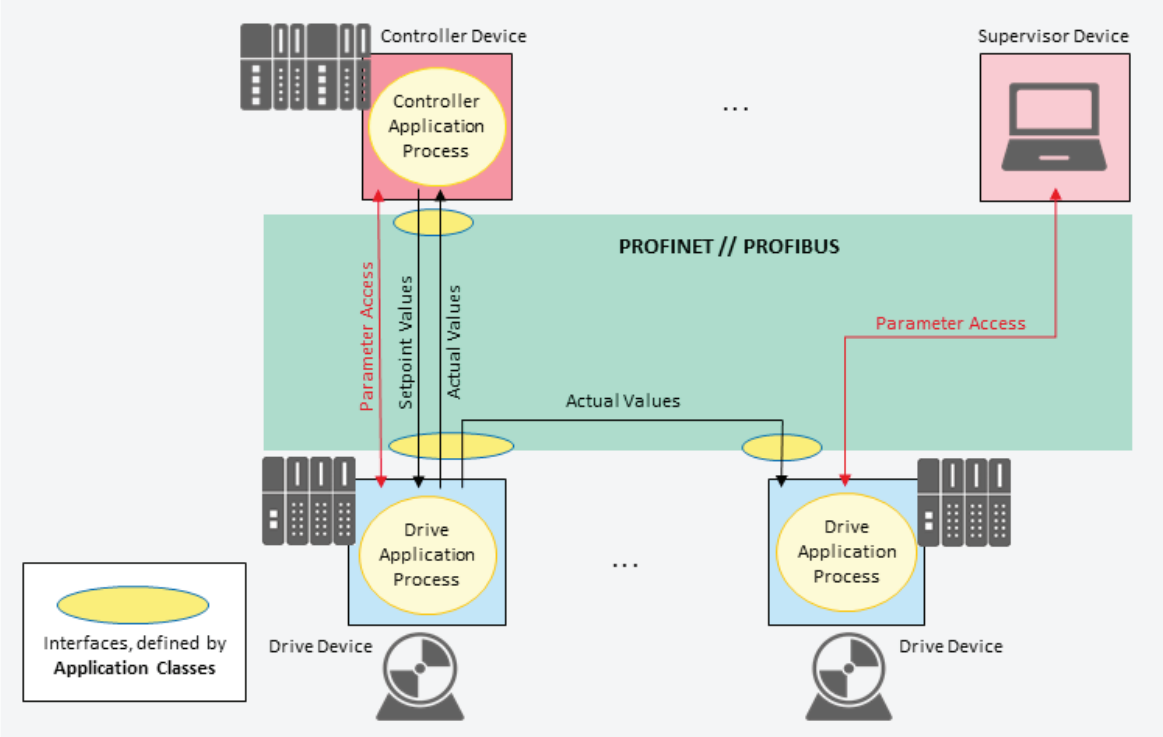


**Fig. 2: General PROFIdrive drive application model**

### 1.3. Safety

Increasingly, the market is showing a trend towards drives that have integrated safety technology. This offers an advantage in the sense that there is no longer any need for external monitoring devices (reduces wiring and saves space). From this point of view, PROFIdrive and PROFIsafe are the perfect complement to one another. Together, the two profiles create a harmonious unit that enables the same bus to be used to control safety functions and standard drive functions. In addition, this enables simultaneous motion control and safety control of a drive (shared device mode).

### 1.4. Energy efficiency

Precisely in the case of drive technology, which is one of the main electrical energy consumers in industrial automation applications, it is very important to conserve the diminishing and increasingly more expensive energy resources as much as possible. PROFIenergy provides a platform that supports standardized control of energy saving features of devices by a higher-level controller. The integration of PROFIenergy in PROFIdrive ensures a consistent solution in this case as well.

## 2. PROFIdrive base model

### 2.1. Device classes

The PROFIdrive base model defines a general drive application (Figure 2) as a set of devices with associated communication relationships (cyclic and acyclic data exchange), irrespective of the communication system used. The following device classes are distinguished for this (Figure 3):

- Controller: Controller or host of automation system, e.g., PLC, NC, or RC
- Peripheral device (P device): Drive device with one or more axes
- Supervisor: e.g., Engineering Station or HMI

## 2.2. Object model in the P device

A PROFIdrive drive device (P device) typically consists of one or more functional objects according to the number of axes. Each of these objects represents the functionality of an axis and is referred to as a drive object (DO).

In particular, multi-axis drive devices can also be modeled consistently with the PROFIdrive object model.

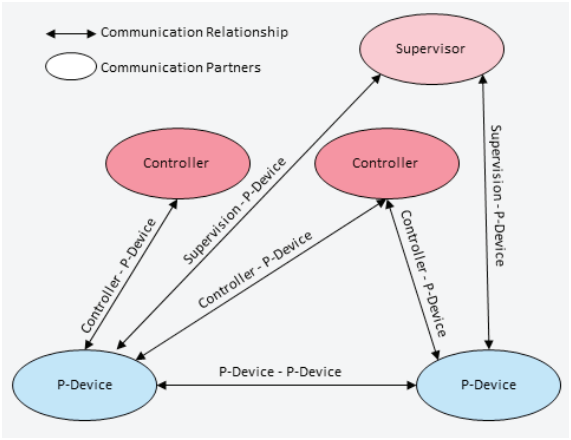


**Fig. 3: Device classes and their communication relationships**

## 2.3. Communication services

### Cyclic data exchange

During operation of a drive application, the open-loop and closed-loop control processes must be activated cyclically (Figure 4, "Process"). From the point of view of the communication system, this means that new setpoints have to be transferred cyclically from the control application processes to the drives and current actual values also have to be sent in the opposite direction. The cyclical transfer can be carried out both isochronously as well as non-isochronously, depending on the requirements of the application and the selected PROFIdrive application class.

### Acyclic data exchange

In addition to the cyclic setpoints and actual values, parameters are used for parameterizing the application processes. The controller accesses these parameters acyclically since this access is not time-critical (Figure 4, "Acyclic data channel"). The parameters can be accessed not only by the controller but also in parallel by a supervisor (commissioning, operator, maintenance station).

### Alarm mechanisms

The alarm mechanism (Figure 4, "Alarm channel") is event-controlled and is used to signal the setting and clearing of maintenance or fault conditions of the drive axis and/or device.

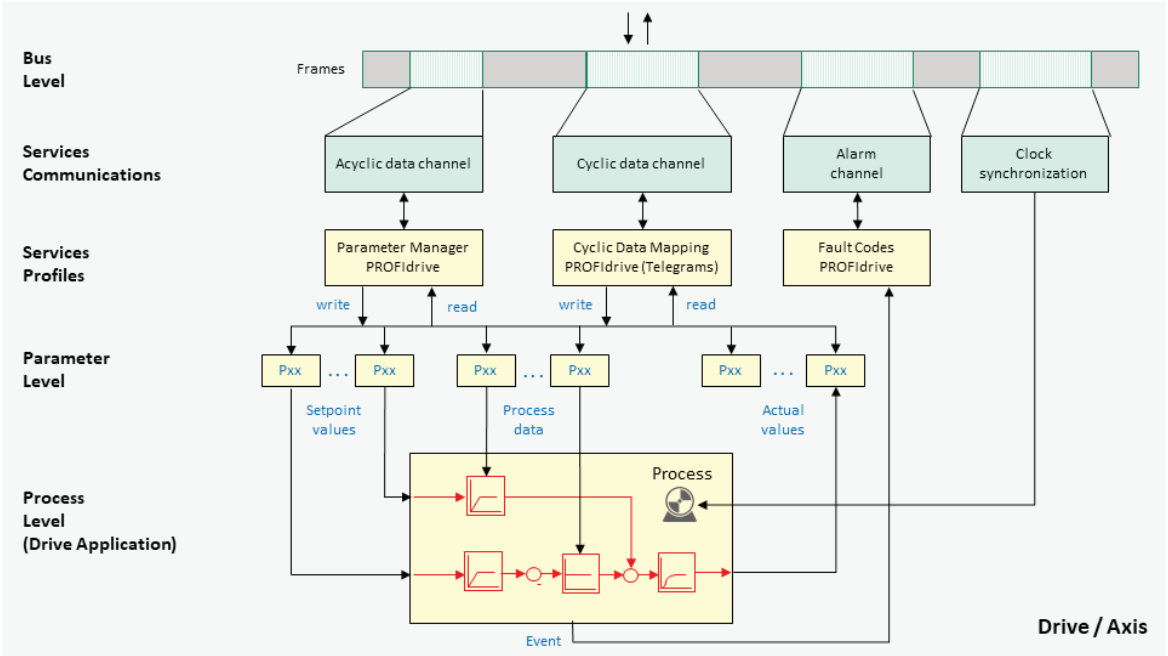


**Fig. 4: Data model and data flows in a drive axis or PROFIdrive drive object (DO)**

### Isochronous operation

Any modern drive profile has to be able to support isochronous operation of distributed drives of a drive application, because this is the only way of accurately coordinating the movements of several axes (such as for path traversing in NC/RC systems or for synchronizing movements associated with electronic gears). This means that a drive profile has to fulfill two basic requirements:

- Synchronization of multiple application processes on different devices to a common master clock
- Assurance that cyclic data exchange between processes is completed reliably by a defined point in time so that all relevant input and output data are available on time for further processing

For process synchronization, PROFIdrive makes use of device clocks that are located in every device and are precisely synchronized with the system's master clock (Figure 5).

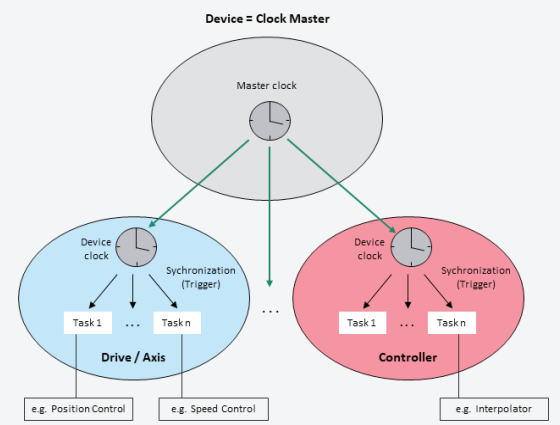


**Fig. 5: Process synchronization in isochronous mode**

For synchronization of the device clocks, PROFIdrive utilizes the appropriate services of the particular communication system. For PROFIBUS, this functionality is an integral component of DP-V2. For PROFINET IO, it is a component of the isochronous realtime functionality (PROFINET with IRT).

For PROFIdrive, isochronous communication is the basis for drive synchronization. Here, it is not just the frame traffic on the bus system that is realized in an equidistant time base. The internal control loop algorithms, for example for speed and current controllers in the drive or for controllers in the higher-level automation system, are also time-synchronized with one another (Figure 5).

For typical drive applications in application classes 4, 5, and 6, the jitter of the clock signal must be guaranteed to be less or equal than 1 µs.

### Device-to-device communication

Device-to-device communication enables direct data exchange between devices without having to transfer data using master/controller. As a result it is possible for drives to receive actual values from other drives with minimum delay. Easy implementation of high-performance, cross-axis control loops is made possible through this.

This opens up new fields of application, especially in distributed drive applications. An example of this is the transfer of speed setpoints for the purpose of creating a setpoint cascade for paper-, film-, wire-, and fiber-drawing machines.

While device-to-device still plays a major role in motion applications with PROFIBUS, it is no longer used in modern motion applications with PROFINET. The reason for this is the significantly increased performance of Profinet which led to the establishement of central PLC-based motion control concepts that are remarkably more covenient to engineer.

## 2.4. PROFIdrive services

### Operating modes and basic state machine

A uniform basic state machine is defined for all application classes in PROFIdrive. It is used to bring the drive to a dedicated operating state or switch off the drive in a defined manner.

For application class 3 "Positioning drive", the basic state machine is extended to include the positioning state machines for controlling the positioning function.

Figure 6 shows the basic state machine (general state diagram) of a PROFIdrive drive. The blue blocks represent drive axis states S1 to S5 and the arrows indicate the state transitions that are possible between them. In case of competing state transitions, priorities are defined by the number of red points shown. The conditions for the state transitions to the yellow boxes are the individual control commands, which are transferred from the controller to the drive axis in the control word with bit coding.

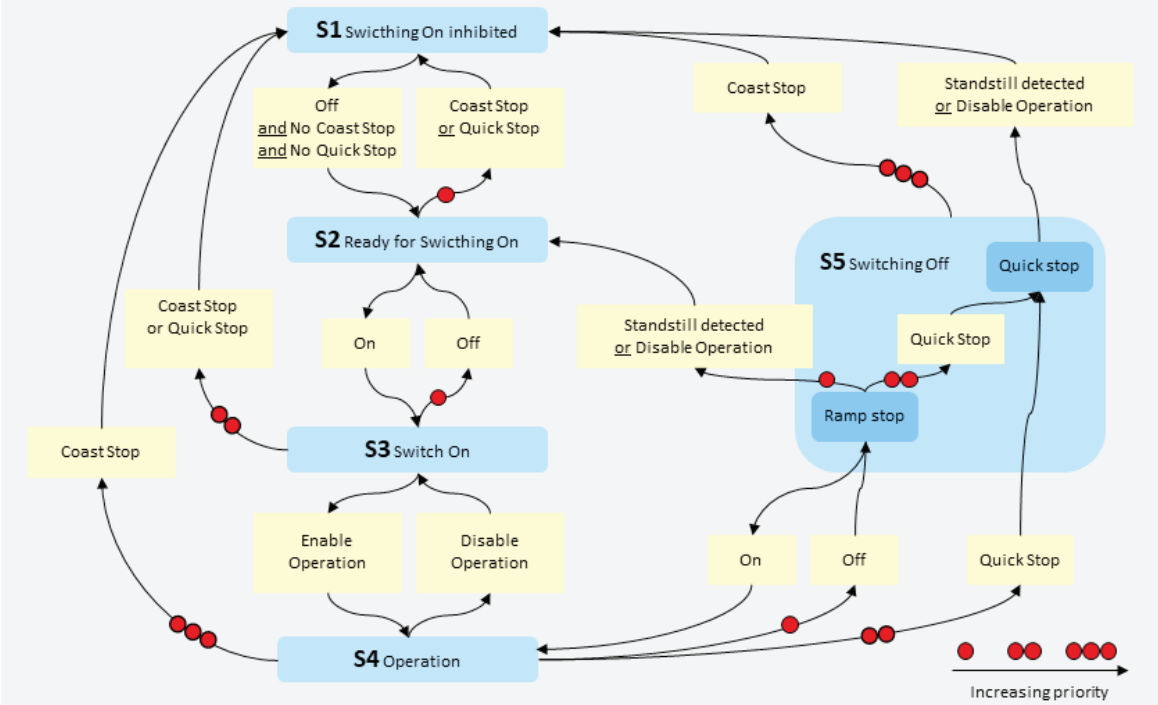


**Fig. 6: Basic state machine of a PROFIdrive drive axis**

### Frames

In cyclic data frames, the control word and the status word form the command interface for the control of the basic state machine by the controller. Individual bits of the control and status words are occupied according to the specific application class.

In addition to the control and status words, the setpoint and actual values of the drive axis are transferred via the cyclic interface.

PROFIdrive describes the cyclic data interface as a string of signals. In this regard, PROFIdrive signals are control and status words as well as setpoints and actual values. The signal number serves to uniquely define the content of a signal as well as its transfer format.

For simplification purposes, typical cyclic interface implementations of PROFIdrive are defined as PROFIdrive frames. Thus, a PROFIdrive frame number signifies a permanently defined grouping of PROFIdrive signals that uniquely describe the cyclic interface.

The PROFIdrive frames are fundamentally identical for both PROFIBUS and PROFINET. A manufacturer can also use additional vendor-specific frames and signals for a specific application case.

### Parameter manager

The PROFIdrive parameter manager, which is operated via the acyclic communication channel, provides users with comprehensive services for accessing the PROFIdrive parameters. Besides reading and writing of parameter values, additional parameter attributes, such as a parameter description, can also be read. To improve performance in the acyclic parameter channel, a multi-parameter service is also defined for the parameter manager.

## 3. PROFIdrive parameter model

PROFIdrive defines a drive model that can already be found today (at least in part) in every drive system. The device comprises various function modules that represent the intelligence of the drive system. These function modules are assigned parameters according to Figure 4, which are used to configure and parameterize the function module (Figure 4, "Process data"). In addition, parameters are also used for internal representation of input and output values of the function module (Figure 4, "Setpoint values", "Actual values"). The function module can be integrated in the cyclic data exchange by interconnecting parameters to the cyclic interface (Figure 4 "Telegrams") accordingly.

The PROFIdrive parameter object has, in addition to the parameter value, additional properties such as the parameter description and the parameter text. This allows Clients to browse generically through the parameter database and read out all parameter properties from the drive that are relevant for the Client (e.g. physical unit, data type, high/low limit value).

The PROFIdrive parameter channel therefore is the basis for the wide range of non-real time-critical tasks in a drive application, such as:

- Parameter assignment and commissioning
- Data backup for device replacement
- Extended diagnostics, such as trace and diagnostics buffer

### 3.1. Profile-specific parameters

The PROFIdrive profile uses parameter numbers from 900 to 999 and from 60,000 to define parameters uniformly for all drives, independently of the application classes. These parameters are designated as profile-specific parameters and ensure interoperability and generic identification of the drive and drive interface.

For example, functions for drive identification, fault buffer, drive control, device identification, and frame configuration and the complete list of implemented parameters are available via profile-specific parameters.

### 3.2. Vendor-specific parameters

Besides the parameters described in the profile, manufacturer-specific parameters can also be used and be differentiated depending on the manufacturer, drive and supported drive functionality. As a result, drive manufacturers can benefit from the advantages of a drive profile without having to forego innovations and unique selling features that provide a competitive edge.

## 4. PROFIdrive application model

According to Figure 2, a drive application consists basically of:

- application processes in the drive, typically motor current control and speed control (Figure 2, bottom), as well as
- application processes in the controller, which may include things like simple speed setpoint setting, position control, or path interpolation (Figure 2, top), and
- a communication system (Figure 2, middle), which provides the relevant services for data exchange and, if necessary, for synchronization between the application processes.

### 4.1 Application classes

The way drives are integrated into automation solutions is heavily dependent on the drive application. There is an extremely broad range of drive applications in automation solutions. A drive device can span six application classes, depending on the market segment and device implementation. In this way, PROFIdrive allow a flexible, manufacturer-specific design of drive products to meet particular market requirements. Depending on the market segment and the type of unit, a drive unit can cover one or more application classes.

**Standard drive (AK1)**

In the simplest case, a main setpoint (e.g. speed setpoint) is used to control the drive in PROFIBUS DP or PROFINET IO (Figure 7). Speed or vector control is handled entirely by the drive. This application is primarily used in conventional variable speed drives (e.g. frequency converters for pumps, fans, compressors). PROFIdrive application class 1 is highly significant to the market and is supported by almost all PROFINET drives.

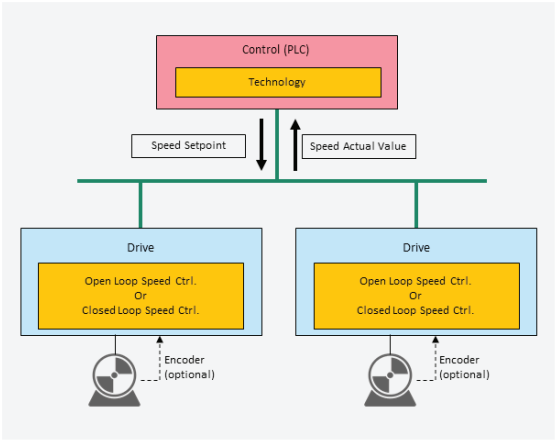


**Fig. 7: Application class 1**

### Standard drive with technological function (AK2)

The standard drive with technology functions is an extremely resource-saving variant for implementing motion applications (Figure 8). With this class, the entire automation process is broken down into several subprocesses and distributed among the drives. The real-time-critical motion functions therefore are not in the central controller and the PROFIBUS DP or PROFINET interfaces take on the character of high-level technological interfaces. Of course, the decentralization of the technological processes requires the ability for multi-directional communication. Thus, device-to-device communication between the technological processes of the individual drives is possible in particular. Specific examples of applications are setpoint cascades, winders and speed synchronization applications for continuous processes that involve a continuously running material web. PROFIdrive application class 2 has often been used with PROFIBUS to save resources on the PLC. AK2 is no longer used in today's systems with PROFINET.

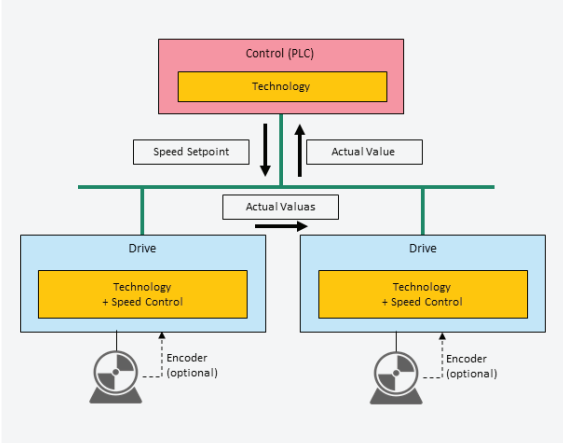


**Fig. 8: Application class 2**

### Positioning drive (AK3)

In this class, the drive features positioning control in addition to the drive control (speed and position control). The drive thus acts as an autonomous single-axis positioning drive, while the higher-level technological processes run on the controller (Figure 9). Positioning tasks are transferred to and started on the single-axis positioner and drive via PROFIBUS DP or PROFINET IO. Positioning drives have a very wide range of applications as seen in positioning drives or in more simple motion applications without path reference. PROFIdrive application class 3 is commonly used for drives with PROFINET and PROFIBUS.

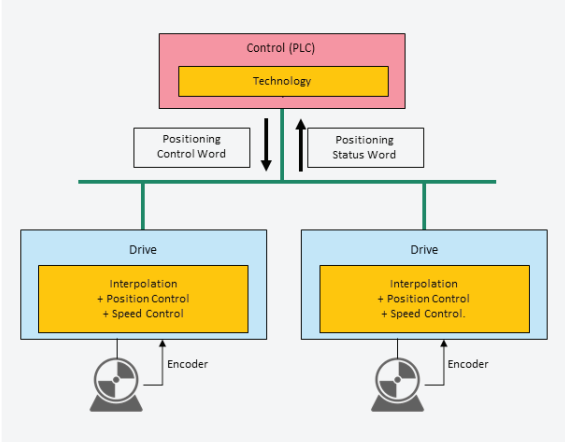


**Fig. 9: Application class 3**

### Central motion control (AK4 and AK5)

Application class 4 defines an interface between the speed setpoint interface and actual position value interface, where speed control is executed on the drive and position control on the controller, as it is typically required in robot and machine tool applications (Figure 10). The motion control for multiple axes is performed centrally, for example, by numerical control (NC). The position control loop is closed by means of the bus. Clock synchronization is required to synchronize the clocks for the position control in the controller and for the speed control in the drives (PROFIBUS DP-V2 or PROFINET with IRT).

Application class 5 is comparable to the above description except that a position setpoint interface takes the place of the speed setpoint interface.

PROFIdrive application class 4 is the standard interface for servo drives on a central motion controller (CNC, RC, MC) and is widely used on PROFINET and PROFIBUS.

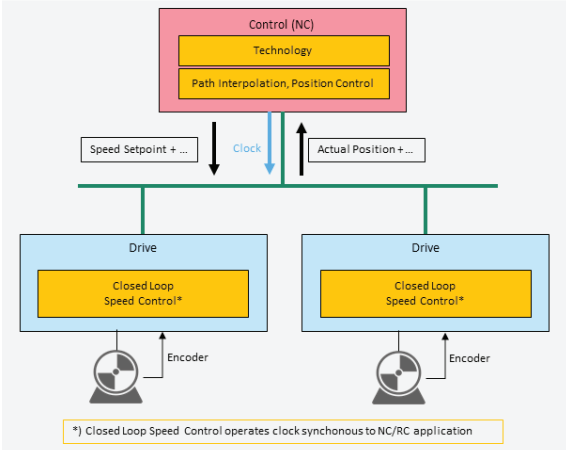


**Fig. 10: Application classes 4 and 5**

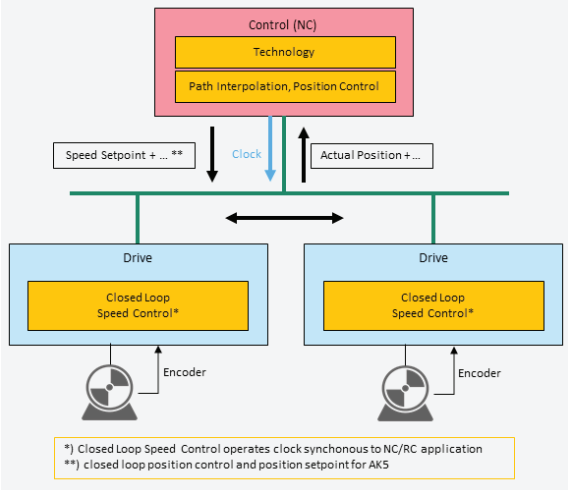


**Fig. 11: Application class 6**

**Decentralized automation with clocked processes and electronic shaft (AK6)**

A resource-saving variant for the implementation of motion applications with angle-synchronous operation, such as "electric gear", "cam disk" or "flying saw". Here, device-to-device communication and clock-synchronous communication are required. The controller (PLC) is not involved in the axis coupling and can be designed to be accordingly economical.

PROFIdrive application class 6 has often been used with PROFIBUS to save resources on the PLC. The AK6 is no longer used in today's systems with PROFINET and instead axis couplings are implemented by corresponding technology objects on the PLC.

These applications are typically implemented with one master drive to which several device drives are synchronized (Figure 11). In this context, the term "master drive" means that a drive axis provides information (e.g. actual position values) to other drive axes. The device drives follow the motion of the master drive by coupling their own drive processes to the drive process of the master with the help of isochronous communication.

## 4.2 Additional functions

The application classes described in the previous section can be extended with optional additional functions.

**Multiple encoder interfaces**

High-precision servo drives typically have other measuring systems besides the motor encoder. PROFIdrive therefore supports up to three position encoders for a drive axis. Accordingly, this encoder information must be passed to the controller through the PROFIdrive interface, and standard frames for multiple encoder channels are provided for this purpose. On principle, the encoder interface can be combined with any application class in which it is necessary to transfer accurate actual position values to the higher-level controller. This is typically the case in application case 4 and 5.

**Dynamic servo control (DSC)**

The innovative dynamic servo control concept included in the profile can be used in application class 4 to improve the dynamic closed-loop performance of mechanically rigid drive systems. This is accomplished by optional feedback of the dynamic disturbance resistance component in the position control loop directly on the drive and in the speed control cycle. For this purpose, (a) an additional feedback network is activated in the drive (Figure 12, "DSC control" box) and (b) the setpoint frame is extended to include the position deviation determined in the upper level controller. The DSC function only serves to improve the disturbance

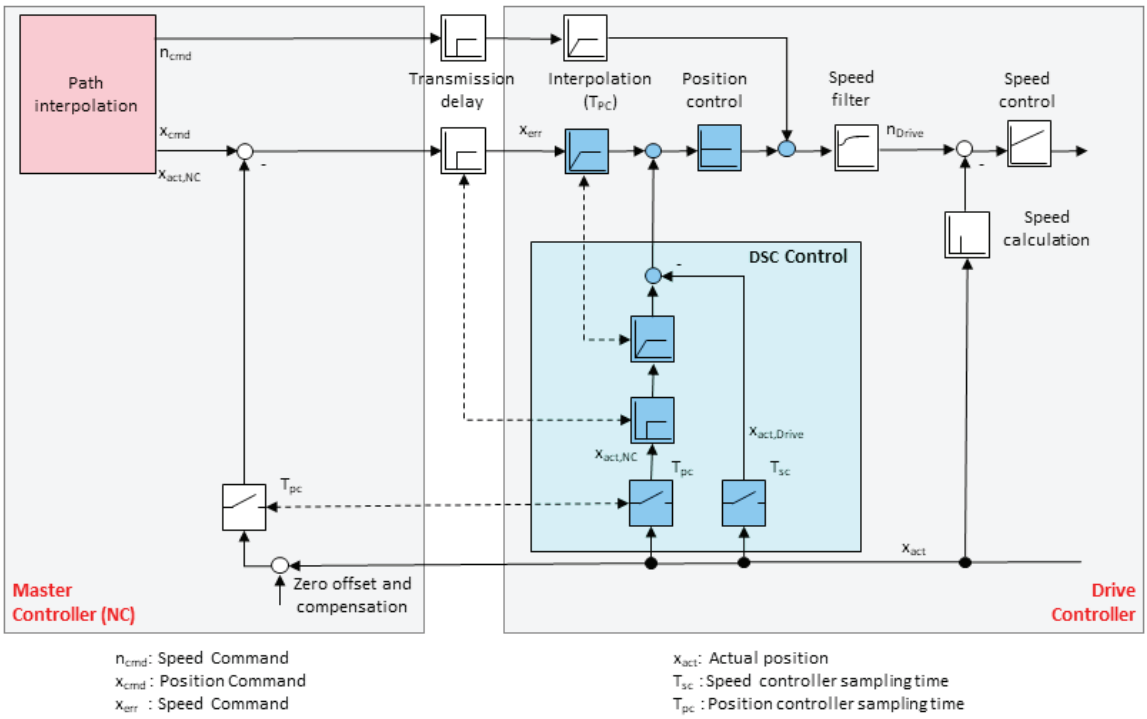


**Fig. 12: Dynamic servo control (DSC) concept**

resistance of mechanically rigid drive systems (e.g. direct drives). In conventional drive systems with low mechanical natural frequencies, DSC is, on principle, unable to improve the control dynamics.

Using DSC enables the basic concept of the AK4 interface to be retained in the controller (absolute value management, cross-axis compensations, homing management in the controller) and to still achieve the maximum possible control performance.

# 5. Diagnostics

Figure 13 shows the range of drive diagnostic functions available with PROFIdrive. These are generally organized into mechanisms for handling warnings and for handling faults. This two-level concept enables emerging problems to be signaled at an early stage so that preventive actions can be taken in time. Drives can thus be easily incorporated into a plant-wide maintenance concept.

## 5.1 Warnings

Warnings are a form of message that is acknowledged automatically as soon as the cause has been addressed. They provide advance warning so that appropriate measures can be taken in good time for the purpose of preventing a fault condition. On principle, several warnings can exist at the same time (e.g. "elevated motor winding temperature" and "DC link voltage too low"). Unlike errors, warnings do not cause the drive to stop.

The profile defines parameters for the warning mechanism, each of which represents a so-called warning word. Each warning that occurs within a drive or drive axis is mapped to one bit of the warning word.

## 5.2 Faults

A fault condition in the drive (e.g. overtemperature) always triggers a device-specific response, i.e., the drive will generally be shut down. At the same time, one or more fault messages describing the fault condition will be entered in the fault buffer (Figure 13).

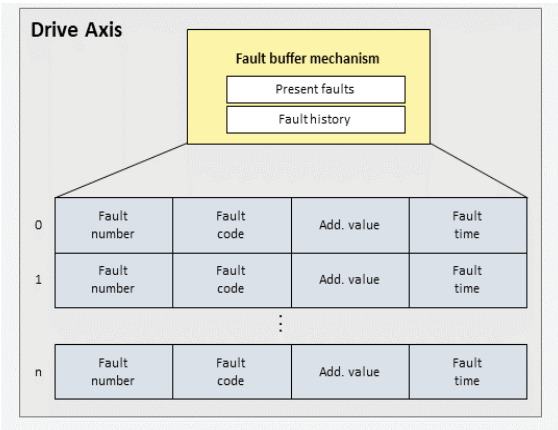


**Fig. 13: Fault buffer mapping to profile parameters**

A fault entry in the PROFIdrive fault buffer consists of the device-specific fault number, an optional application-specific fault code, and an optional associated value or fault time (Figure 14). The device-specific fault number and fault code information enables very detailed device-specific diagnostics.

Whenever the cause of a fault is eliminated, the user must always explicitly acknowledge the fault by means of a command. The acknowledged fault is not deleted but rather archived in the fault buffer, which allows subsequent tracking of faults. The size of the fault buffer can be specified on a device-specific basis.

### 5.3 Integration into standard diagnostic mechanisms

For cross-vendor diagnostics, PROFIdrive provides a simplified profile-specific diagnostics view of PROFIdrive fault classes (Figure 13, "Fault classes mechanism") in addition to the detailed diagnostics view of fault buffers and warning words. With the help of the PROFIdrive fault classes, it is possible to achieve a uniform and consistent diagnostics view for all PROFIdrive drives, in which fault classes are structured according to typical modules and function blocks of a drive and which supports users and service personnel in carrying out fast, systematic trouble-shooting.

These warnings and faults are signaled as alarm objects (fault, maintenance demanded, maintenance required) to the higher-level controller via the standard PROFINET alarm channel. This ensures consistent integration of the PROFIdrive drive into the standard diagnostics system of PROFIBUS and PROFINET.

## 6. Additional profiles

In addition to traditional drive functions such as speed, position, and motion control, drives are integrating more and more additional functions, which were previously implemented externally but are now included in the drive. Two typical examples

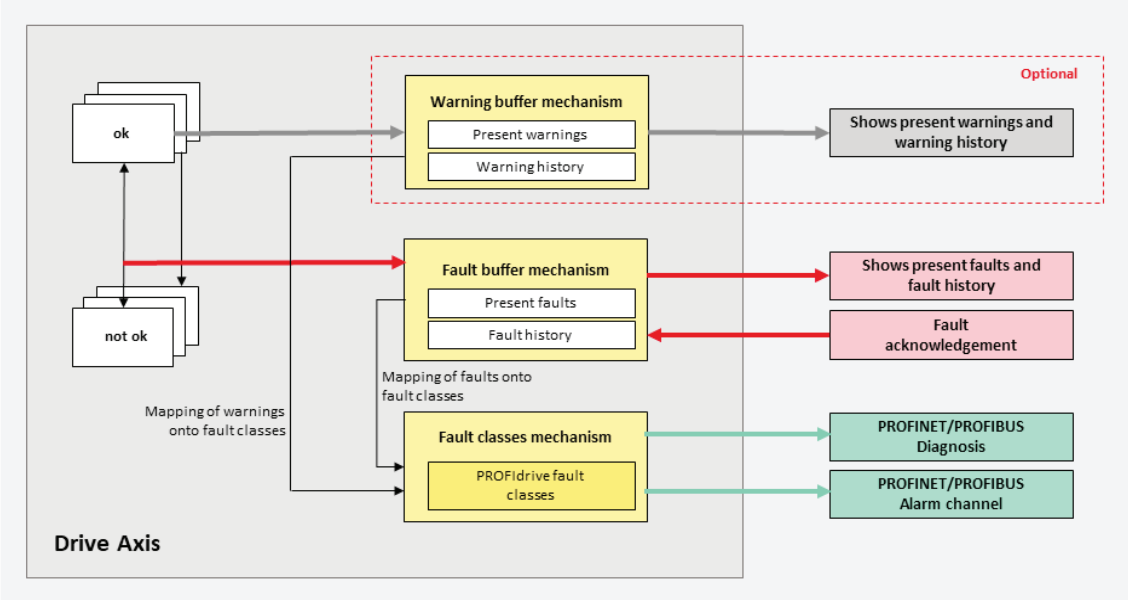


**Fig. 14: PROFIdrive diagnostic functions**

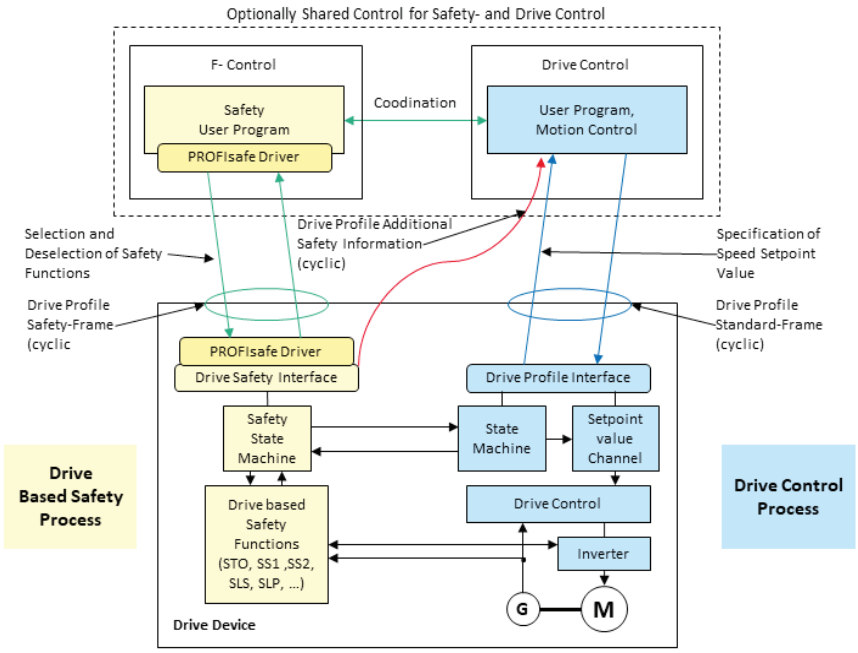


**Fig. 15: Integration of drive-based safety in the drive device**

of this are drive-based safety technology and energy management functions. These additional drive functions require new communication relationships with additional communication profiles. Drive technology is therefore a typical example of PROFIBUS and PROFINET devices that not only support their original application profile but also other additional profiles (common application profiles). To ensure smooth interaction between these additional functions and the basic PROFIdrive functions, definitions and specifications regarding this interaction have been inluded in PROFIdrive.

## 6.1 PROFIsafe

Integration of safety technology into the drive is beneficial because it eliminates the need for external monitoring devices, thereby reducing wiring expenses and space requirements. From this point of view, the PROFIdrive and PROFIsafe profiles are the perfect complement to one another. Together, the two profiles create a harmonious unit that enables the same bus to be used to control safety functions and standard drive functions (Figure 15).

The safety functions on the drive are controlled by means of cyclic frame exchange with a higher-level safety user program via a safe PROFIsafe transmission channel. For purposes of efficient operation, it is very important to coordinate the sequences on the F-controller with those on the drive control. Thus, for example, preliminary measures such as speed reduction or motion restrictions must be taken on the motion control drive before selecting safety functions, which explains why the drive control requires direct information exchange with the F-controller and with the safety process on the drive (additional safety information). In this case, PROFIdrive defines standardized flexible extensions for standard frames that can be used in all application classes.

The shared-device concept of PROFINET IO enables standard and safety functions to be distributed among different physical controllers/PLCs, thereby significantly expanding the usability of integrated safety technology.

The PROFIdrive profile supports the Drive Based Safety functions STO, SS1, SS2, SOS, SLA, SDI, SLS, SLP, SS, SP and SCAM in the PROFIdrive on PROFIsafe amendment.

## 6.2 PROFIenergy

Electric drives account for a large portion of industrial power demand. With continuously rising energy prices, this cost factor is driving up production costs more and more. On the positive side: this represents an enormous savings opportunity for practically all companies. Especially in high energy-consuming areas, significant savings are possible through the use of energy-efficient drives and intelligent energy management. This is where PROFIenergy comes in by providing a uniform, device-/vendor-neutral

interface for controlling energy saving functions in PROFINET devices. Figure 16 shows the possible uses of PROFIenergy for a PROFIdrive drive.

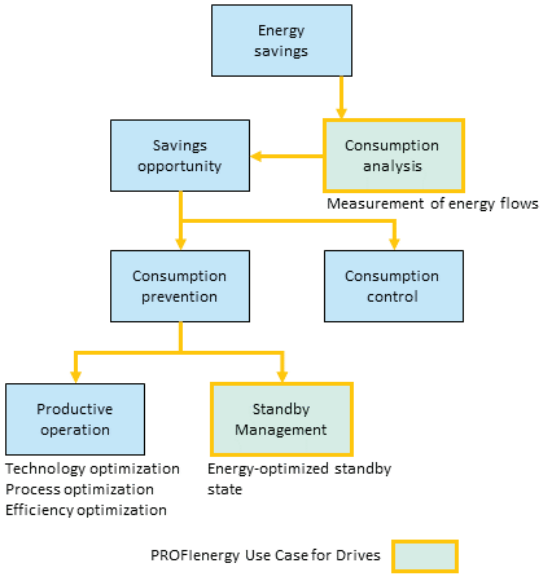


**Fig. 16: Starting points for energy savings in the field drive technology**

### Consumption analysis

For the consumption analysis, it is necessary to systematically measure the energy flows in the plant using a higher-level energy management system. Modern drive technology is equipped with sensors for current and speed control and, thus, performance data measurements already exist. However, up to now these data have not been made available at all or have been provided only a manufacturer-specific basis. Standardization of the energy information functions in PROFIenergy means that the drive can be easily integrated into the consumption analysis, thereby eliminating the need for additional costly energy measuring devices. In addition, the performance and energy measurements for the drive can also be used for process and plant diagnostics.

### Standby management

The standby management function of PROFIenergy can be used to place the idle PROFIdrive drive in an energy-optimized standby state. In so doing, PROFIenergy communicates the expected idle time duration to the drive. The drive can shut down subprocesses or subcomponents as appropriate based on the idle time duration. To activate standby state, the drive must be deactivated by its application. That is, before a drive is placed in standby state, it must first be switched to S2 mode by its drive control.

# 7. Mapping to PROFIBUS and PROFINET

## 7.1 Mapping to PROFIBUS DP

If PROFIdrive is being used on PROFIBUS DP, then the PROFIdrive base model will be mapped to this communication system in accordance with Figure 17. For standard applications in application classes 1 and 3, PROFIBUS DP-V1 is sufficient. For applications with clock synchronization and device-to-device communication (AK4, AK6), PROFIBUS DP-V2 is required.

The devices of the PROFIdrive base model are mapped as follows:

- The PROFIdrive controller corresponds to the class 1 PROFIBUS DP Master
- The PROFIdrive peripheral device (P device) corresponds to the PROFIBUS DP Device
- The PROFIdrive supervisor corresponds to the class 2 PROFIBUS DP Master

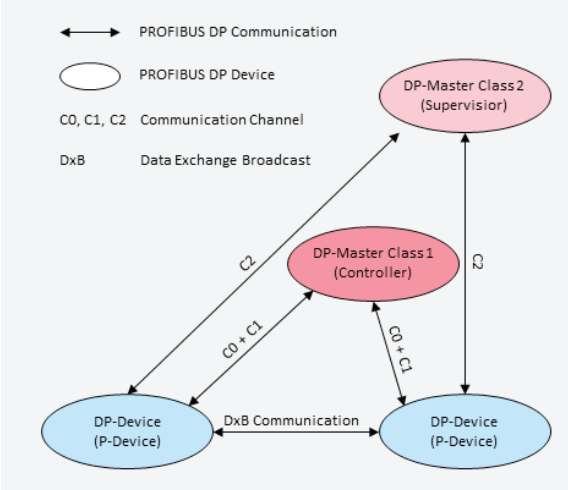


**Fig. 17: Mapping of base model to PROFIBUS DP**

## 7.2 Mapping to PROFINET IO

In version 4 or higher, the PROFIdrive profile can also be used with the PROFINET IO communication system.

If PROFIdrive is being used on PROFINET, then the PROFIdrive base model is mapped to PROFINET IO in accordance with Figure 18. Either PROFINET IO with RT or IRT is used depending on the application.

The devices of the PROFIdrive base model are mapped as follows:

- The PROFIdrive controller corresponds to the PROFINET IO Controller
- The PROFIdrive peripheral device (P device) corresponds to the PROFINET IO Device
- The PROFIdrive supervisor corresponds to the PROFINET IO Supervisor

The control application processes run on the PROFINET IO Controller. A drive with one or more drive axes is referred to as a drive unit and is mapped to PROFINET IO as an IO Device. A PROFINET IO application relationship (IOAR) is established between the IO Controller and the drive unit of an IO Device (Figure 18). This is used to define cyclic data exchange, parameter access, and the alarm channel.

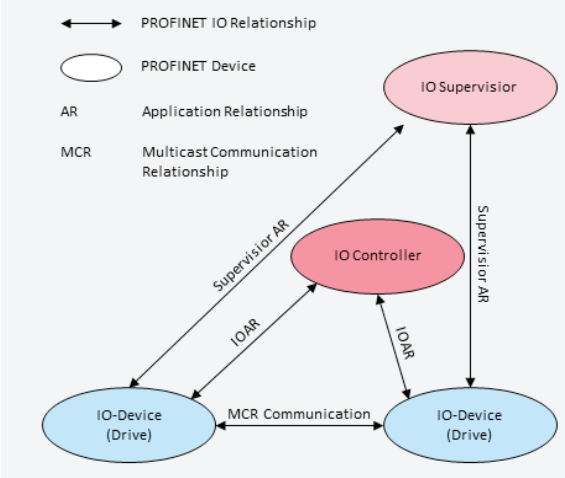


**Fig. 18: Mapping of base model to PROFINET IO**

# 8. Conformity and certification

In order for products of different types and manufacturers to perform their automation tasks reliably, their behavior on the bus must comply fully with the standard. This requires error-free implementation of the communication protocols and application profiles by the device manufacturer. In spite of taking great care, manufacturers of these complex devices cannot always guarantee that this is the case, so that an independent certification of the bus interface and the device behavior is necessary.

## 8.1 Quality control through certification

To ensure that products are implemented in compliance with the standards, PI has established a quality assurance procedure. Only through a faultless test result positive test reports are issued by accredited PI Test Laboratories (PITLs), which form the basis for issuing a PI certificate. The basic process for this device certification is shown in Figure 19.

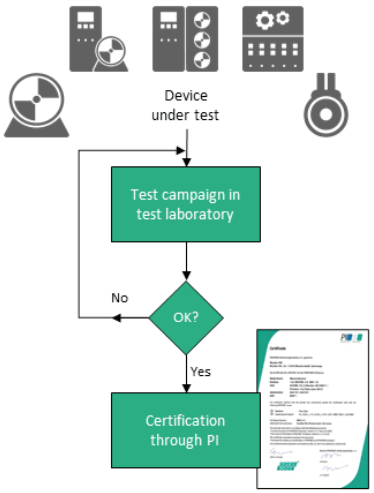


**Fig. 19: Procedure for obtaining a certificate**

The aim of certification is to provide users with an assurance that devices from different manufacturers are capable of fault-free operation when used together. For this purpose, the devices are tested by independent test laboratories under lifelike conditions in accordance with the appropriate test level. This makes it possible to identify any implementation errors of the standards by developers at an early stage so that manufacturers can take the necessary remedial action before devices are implemented in the field. The test also examines the device's compatibility with other certified devices. Upon successful completion of the test, the manufacturer can apply for a device certificate.

The certification procedure is based on EN 45000. In accordance with the requirements of this standard, the test laboratories accredited by PI are not linked to any specific manufacturer. Only the PITLs (PI Test Labs) can perform the device tests required for awarding the certificate. The test procedure and the certification process are described in the relevant PI guidelines. Together, the quality system and accreditation procedure ensure a consistent level of testing quality in all PITLs.

## 8.2 PROFIdrive certification

PI certification ensures that the devices of different manufacturers with different functional scopes conform to the PROFIdrive profile specification. The test report of a PITL serves as the basis for awarding a PROFIdrive certificate.

The PITL uses the PROFIdrive Profile Tester to carry out the certification test. The Profile Tester allows the tests to be performed automatically to a great extent.

Figure 20 shows the basic structure of the PROFIdrive Profile Tester. The drive to be tested (test sample) is connected to the Profile Tester and undergoes an automated test based on script descriptions. The results of the individual test steps are recorded automatically in a corresponding log.

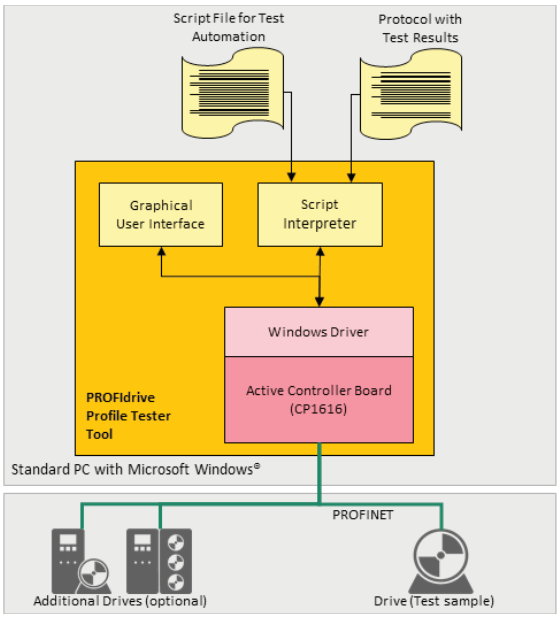


**Fig. 20: Conformity test with the PROFIdrive Profile Tester**

The PROFIdrive Profile Tester is available to device manufacturers for development support and for preliminary testing purposes. It thus helps manufacturers to achieve fast, systematic implementation of the PROFIdrive profile into products.

# 9. PROFIdrive implementation

To keep the initial effort required for implementing a PROFIdrive profile in a company's own products as low as possible, the companies participating in the PROFIdrive Community have set up a working group known as the PROFIdrive Community Project.

The aim of this project is to support interested manufacturers as comprehensively as possible in the flawless and rapid implementation of devices with their own PROFIdrive profile interface.

One essential approach applied by the Community Project is to provide these manufacturers with tried and tested software components to enable in-house implementation, eliminating the need to reinvent the wheel every time a PROFIdrive profile interface is introduced.

This enables the effort required for implementation to be significantly reduced and makes it simpler to ensure later error-free function in the field.

As well as offering the use of a previously established source code, the Community Project also supports the implementation of a PROFIdrive profile interface with further offers. For example, there is an Implementation Guide enabling reliable implementation of smooth communication and interaction between drive, controller and encoder, depending on the application class. (Figure 21)

The benefit of the Implementation Guide can be regarded as similarly high to the possibility of including previously established source codes with support from the Community Project.

The Implementation Guide was developed to help with the following tasks:

Provide a quick overview of all necessary functionalities that need to be considered for a successful implementation of a PROFIdrive device interface.

This enables a time-efficient independent assessment of the implementation effort without the need for familiarization with detailed profile specifications of the PROFIdrive standard.

Particular emphasis was placed on clarity when creating the Implementation Guide; all functionalities are grouped into function blocks and their interaction is explained in detail using function plan diagrams.

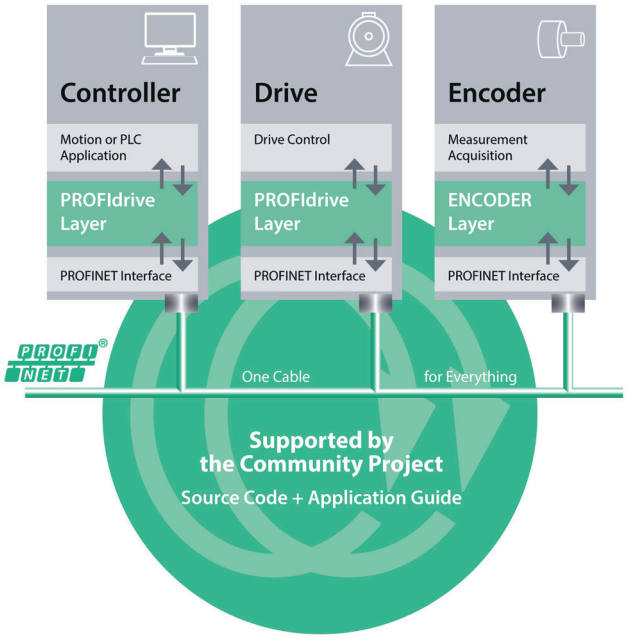


**Fig. 21: How the Community Project works**

The different effort required to implement a specific PROFIdrive application class (AC1 - AC6) is clearly established and a selection of required functions for the two most common application classes AC1 and AC4 are worked out as examples.

Another clear aid for implementation both when starting with the comparatively simple frequency inverter interface (AC1) and also for a more complex implementation of a servo drive interface (AC4).

Individual PROFIdrive functions have also been characterized making it very easy to assess whether the implementation is mandatory or optional for the interface type in question according to the PROFIdrive standard. There are also recommendations that help to assess whether it makes sense to implement an optional function or not.

The considerable years of experience that the manufactures bring to the Community Project provide information on special functions that goes beyond the scope described in the standard based on many years of practical experience.

For each function block in the application guide, reference is made to the exact section, pages and figures/tables in the PROFIdrive Profile specification V4.2 standard in which this functionality is described in detail. As such, the Implementation Guide is therefore fundamentally suitable as a guideline for the PROFIdrive profile.

Excel spreadsheets that can be used a starting point for your in-house develeopement are also provided and can be used as well as a starting point for your in-house development plan and can also be used as a well-proven means to track interface development. Figure 22 shows some of the main implementation aids mentioned above and the benefits that they provide over and above entirely independent implementation.

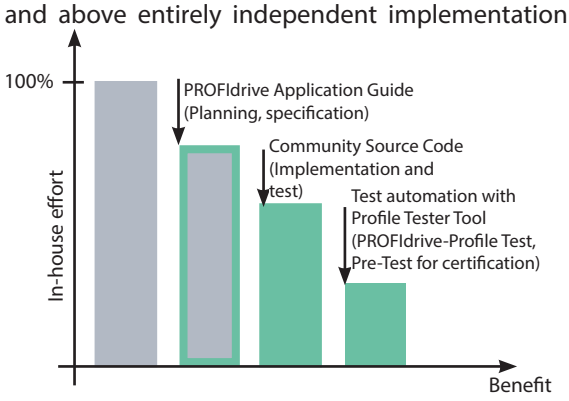


**Fig. 22: Contents and benefits of the Community Project**

Summary of the beneficial services available through the Community Project:

- **Implementation Guide**
  Designed to serve as a planning aid, the PROFIdrive Application Guide lists in detail all the subfunctions to be implemented for each application class and provides valuable implementation tips.

- **Reference implementation via a license-free source code**
  The community source code (AC1 + AC4) is available as various implementation projects for a PROFIdrive layer for controllers, drive devices and encoders on various platforms and PROFINET stacks and is available to everyone free of charge. Proven in field operation, usable on various platforms and operating systems.
- **FAQ + version overview report**
  Which special features were found in the software, from which version are they taken, etc.?
- **Free file download**
  Software; overviews, manuals; etc.
- **Use of the profile tester at an early stage during the implementation phase**
- **Support from the PROFIdrive Community companies**

Informations about the PROFIdrive Community Project can be found at www.profibus.com/technology/profidrive/community-project/.

# 10. Engineering

**Tool Calling Interface (TCI)**

Today's powerful drives contain a wide range of functions, from the control functionality for current, voltage, and speed and technological functions such as ramp generators and various monitoring activities all the way to logic functions for sequential control of simple operations. Each of these functions requires parameter assignment of varying complexity. Commissioning tools that are adapted to the respective devices are available to drive manufacturers for this purpose.

PI has developed the tool calling interface (TCI) concept for the purpose of integrating drive commissioning tools into the central engineering system of a plant (typically the engineering tool of the PLC). The TCI can be used to call existing drive commissioning tools from the central PLC engineering (Figure 23). The advantage of this is that a drive specialist can continue to access his familiar user interface to commission and diagnose drives. On the other hand, the TCI concept ensures that the configuration data of commissioning tools integrated in this way are stored in a central PLC project.

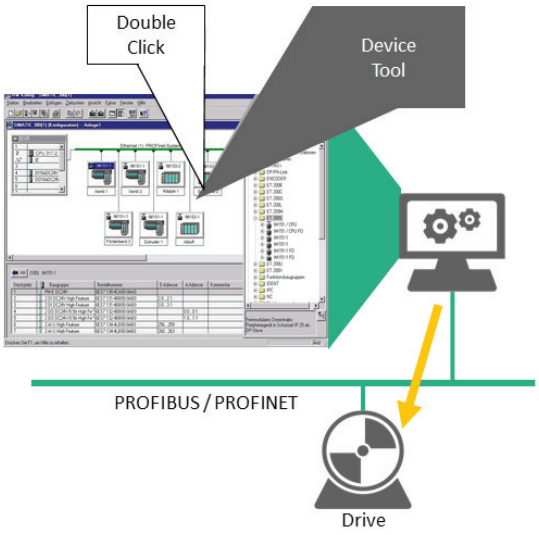


**Fig. 23: Easy engineering of drive integration using TCI**

The TCI also specifies an open communication channel from the drive commissioning tool through the PLC programming system, which allows the familiar drive commissioning tool to be used even for online access.

# 11. User benefits

Over 30 million PROFIBUS devices are currently installed. Therefore, the top priority for development has always been and will continue to be ensuring that the system remains fully compatible with the devices that are already on the market.

Thanks to the identical application view and common base and application models, it is even possible to switch over from PROFIBUS to PROFINET without any major difficulties.

The following statements sum up the user benefits perfectly: "Integration instead of interfaces" and "One technology instead of multiple technologies".

It is on this basis that PROFIdrive is able to achieve significant cost reductions over the life cycle of a plant or machine for: planning, installation, operation and maintenance as well as expansions and upgrades. The integration of PROFIdrive is made possible by the use of the standard communication protocols PROFIBUS DP and PROFINET IO, which are capable of meeting the diverse requirements of production and process automation and motion control and safety applications in equal measure.

The PROFIdrive application profile is oriented to the special requirements of drive technology in conjunction with the PROFIBUS and PROFINET communication systems and offers unrivaled scalability of communication performance. It creates multiple benefits not only for the device and system manufacturers but also for integrators and end users.

There are considerable cost advantages to be achieved by using a single, integrated communication solution for the drives, the controller, the I/Os, and operator control and monitoring.

The integrated approach pays off not only for planning and installation but also for training, documentation and maintenance, because only a single technology is involved.

Drive tasks of every conceivable type, each of which will have its own specific requirements, can be addressed in a standard yet flexible way thanks to the integrated technology, the integrated application programs, and the scalable communication performance.

The need for user-friendliness is fully met by ensuring the interoperability and interchangeability of devices from different manufacturers and the availability of standardized program libraries from well-known PLC manufacturers. The reliable operation of the devices is guaranteed thanks to independent certification by accredited test laboratories.

Because PROFIdrive has been standardized in IEC 61800-7, international acceptance is guaranteed and investments enjoy extensive long-term protection. This protection is further reinforced by the fact that PROFIdrive is based on the world-leading PROFIBUS and PROFINET technologies. The fact that the profile is also recommended by user organizations such as OMAC and VIK NAMUR has a similar positive effect.

# 12. PROFIBUS & PROFINET International (PI)

As far as maintenance, ongoing development and market penetration are concerned, open technologies need a company-independent institution that can serve as a working platform. This was achieved for the PROFIBUS and PROFINET technologies by the founding of the PROFIBUS Nutzerorganisation e.V. (PNO) in 1989 as a non-profit interest group for manufacturers, users and institutions. The PNO is a member of PI (PROFIBUS & PROFINET International), an umbrella group which was founded in 1995. With its 25 regional associations (RPA) and approximately 1,700 members, PI is represented on every continent and is the world's largest interest group for the industrial communication field (Figure 24).

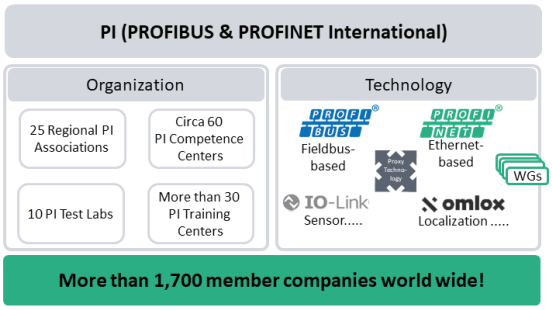


**Fig. 24: PROFIBUS & PROFINET International (PI)**

### Responsibilities of PI

The key tasks performed by PI are:

- Maintenance and ongoing development of PROFIBUS and PROFINET.
- Promoting the worldwide use of PROFIBUS and PROFINET
- Protection of investment for users and manufacturers by influencing the development of standards.
- Representation of the interests of members to standard bodies and unions.
- Providing companies with worldwide technical support through PI Competence Centers (PICC).
- Quality control through product certification based on conformity tests at PI Test Labs (PITL).
- Establishment of a worldwide training standard through PI Training Centers (PITC).

### Technology development

PI has handed responsibility for technology development over to PNO Germany. The Advisory Board of PNO Germany oversees the development activities. Technology development takes place in the context of more than 40 working groups with input from over 1,000 experts, mostly from engineering departments of member companies.

### Technical support

PI supports circa 60 accredited PI Competence Centers (PICCs) worldwide. These facilities provide users and manufacturers with all manner of advice and support. As institutions of the PI, they are independent service providers and adhere to

the mutually agreed regulations. The PICCs are regularly checked for their suitability as part of an individually tailored accreditation process. A list of the current PICC locations can be found on the web site.

**Certification**

PI supports 10 accredited PI test labs (PITL) worldwide, which assist in the certification of products with a PROFIBUS/PROFINET interface. As institutions of the PI, they are independent service providers and adhere to the mutually agreed regulations. The testing services provided by the PITLs are regularly audited in accordance with a strict accreditation process to ensure that they meet the necessary quality requirements. A list of the current PITL locations can be found on the web site.

**Training**

Approximately 30 PI Training Centers (PITC) have been set up with the aim of establishing a global training standard for engineers and technicians. The accreditation of the Training Centers and the experts that are based there ensures the quality of the training and, thus, the quality of the engineering and installation services for PROFIBUS and PROFINET. A list of the current PITC locations can be found on the web site.

**Internet**

Current information on PI and the PROFIBUS and PROFINET technologies is available on the PI web site www.profibus.com or www.profinet.com. This includes, for example, an online product finder, a variety of web-based training content and the download area containing specifications, profiles, installation guidelines and other documents.

## Space for your notes

# PROFIdrive System Description
# Technology and Application

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**For additional information go to:**
**www.profibus.com/technology/profidrive**

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