Overview

Most production machines use digital communication bus systems. These handle the communication between the control level, the machine control and the executing components, i.e. the sensors and actuators. There are two types of communication: process communication and data communication.

Process communication

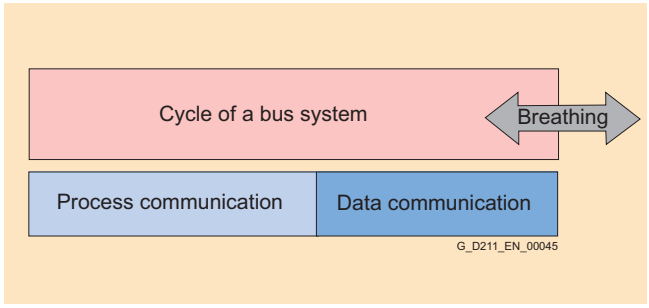
Process communication involves cyclically transmitting control data and setpoints. The quantity of transfer data is comparatively small. For example, a drive can communicate with between 4 and 32 bytes. The number of connected sensors and actuators is usually specified by the configuration which makes the bus cycle of process communication very constant.

Data communication

Data communication is often required for engineering and is not directly linked to the execution of the production process. Data are sporadically (acyclically) exchanged with connected devices. The volume of this communication can be very large with over 100 bytes per device and communication task.

Bus cycle

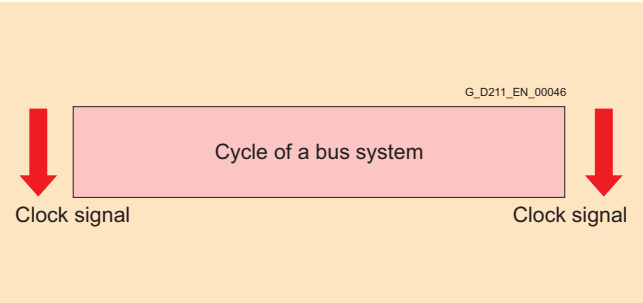
The bus cycle comprises of process communication and data communication. The cycle of the bus system is much shorter without data communication. Some say: the bus cycle breathes. However, this breathing is unsuitable for highly accurate applications in drive technology.



Communication types of a bus system

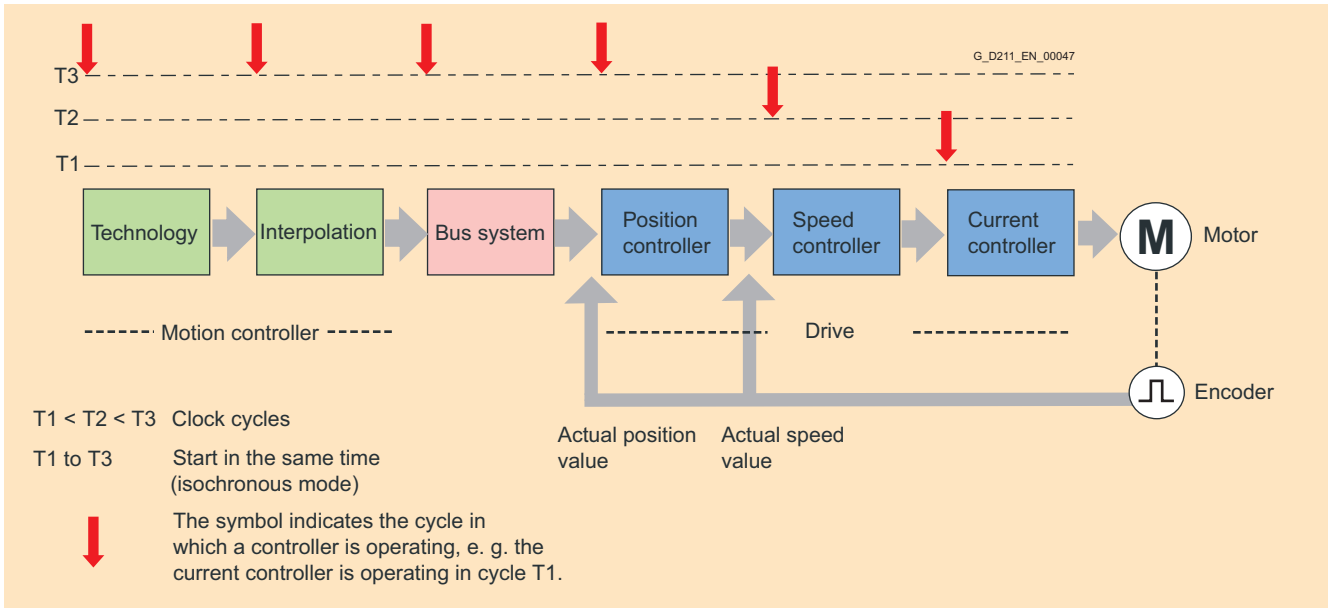
Requirements of drive controls

Most modern drives have a digital closed-loop control. This closed-loop control ensures that the controlled variable of the drive, for example the speed or position, are achieved and maintained. This type of digital closed-loop control comprises several intertwined controls (position, speed, current, ...). These must be matched to one another, i.e. they must be synchronized. This synchronization is important to keep the controls stable and to accurately maintain the controlled variable and/or to achieve it quickly. If some of the components of the closed-loop control are located outside the drive, a bus system must be used to manage the communication between these components. This bus system must be as synchronized as the closed-loop controls. This is referred to as isochronous operation. For drives in the area of Motion Control Systems isochronous operation must be extremely quick and very accurate. It ensures that the length of the bus cycle deviates only very slightly. This is then no longer referred to as the breathing of the bus cycle (large deviations), but as jitter (small deviations). Acceptable values are <1 µs. This synchronization is achieved through clock signals.



Constant bus cycle

So that a bus system can be used for Motion Control applications it must permit process communication and isochronous operation. An additional bus system is often used for data communication. PROFIBUS and PROFINET can combine all of these requirements in a single bus system. Industrial Ethernet, the predecessor of PROFINET, does not fulfill the requirements with respect to real-time communication.



The principle of digital drive controls

PROFIdrive

Overview

What are profiles?

Profiles used in automation technology define certain characteristics and responses for devices, device groups or whole systems which specify their main and unique properties. Only devices with manufacturer-neutral, identical profiles can "interoperate" on a fieldbus and thus fully exploit the advantages of a fieldbus for the user.

Profiles are specifications defined by manufacturers and users for certain characteristics, performance features and behaviors of devices and systems. They aim to ensure that devices and systems which belong to one product family by virtue of their "product-compliant" development are interoperable and, to a certain degree, exchangeable in bus operation.

Profile types

Different types of profile can be distinguished as so-called application profiles (general or specific) and system profiles:

- Application profiles
  mainly refer to devices (drives) and contain an agreed selection of bus communication modes, as well as specific device applications.
- System profiles
  describe system classes and include the master functionality, program interfaces and integration methods.

PROFIdrive

The PROFIdrive profile is a specific application profile.

Design

PROFIdrive in drive applications

The PROFIdrive profile defines the device behavior and the access procedure to drive data for electrical drives on PROFIBUS, from simple frequency converters up to high performance servo controllers.

It contains a detailed description of how the communication functions "slave-to-slave communication", "equidistance" and "isochronous operation" are used meaningfully for drive applications. In addition, it specifies all device characteristics which influence interfaces connected to a controller over PROFIBUS or PROFINET. This includes the sequence control system, encoder interface, standardization of values, definition of standard messages, and access to drive parameters, etc.

The PROFIdrive profile supports both central and distributed Motion Control concepts.

The basic philosophy: Keep it simple

The PROFIdrive profile tries to keep the drive interface as simple as possible and free from technology functions. This philosophy ensures that reference models, as well as the functionality and performance of the PROFIBUS/PROFINET master, have no or very little influence on the drive interface.

Segmentation into application/utilization categories

The integration of drives into automation solutions depends heavily on the drive task. To cover the extensive range of drive applications from the most simple frequency converter up to highly dynamic, synchronized multi-axis systems with a single profile, PROFIdrive defines six application categories which cover most drive applications.

- Category 1 – Standard Drives (such as pumps, fans, stirring units, etc.)
- Category 2 – Standard Drives with Technology Functions
- Category 3 – Positioning Drives
- **Category 4 – Motion Control Drives with Central, Higher-Level Motion Control Intelligence**
- Category 5 – Motion Control Drives with Central, Higher-Level Motion Control Intelligence and the Patented "Dynamic Servo Control" Position Concept
- Category 6 – Motion Control Drives with Distributed Motion Control Intelligence Integrated in the Drives

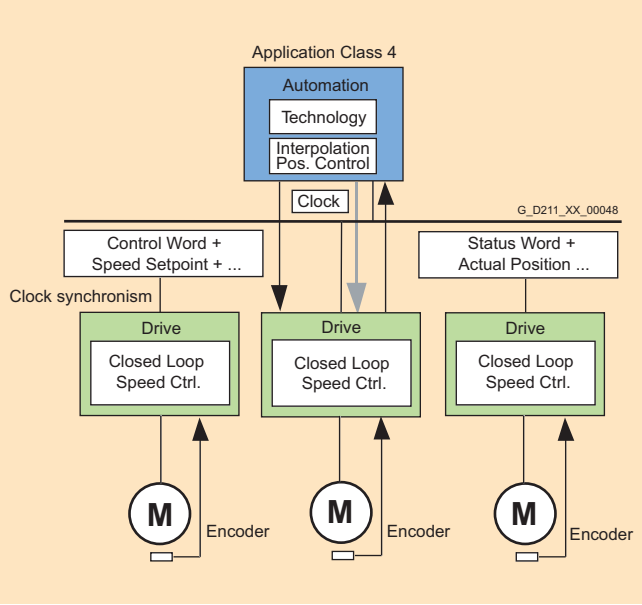
Design (continued)

PROFIdrive defines a device model based on function modules which cooperate in the device and generate the intelligence of the drive system. These modules have objects assigned to them which are described in the profile and are defined with respect to their functions. The overall functionality of a drive is therefore described through the sum of its parameters.

In contrast to other drive profiles, PROFIdrive defines only the access mechanisms to the parameters as well as a subset of profile parameters (about 30) such as the fault buffer, drive control and device identification.

All other parameters are vendor-specific which gives drive manufacturers great flexibility with respect to implementing control functions. The elements of a parameter are accessed acyclically over the so-called DP-V1 parameter channel.

As a communication protocol, PROFIdrive uses DP-V0, DP-V1, and the DP-V2 expansions for PROFIBUS including the functions "Slave-to-Slave Communication" and "Isochronous Operation", or PROFINET IO with real-time classes RT and IRT.



PROFIdrive and SINAMICS

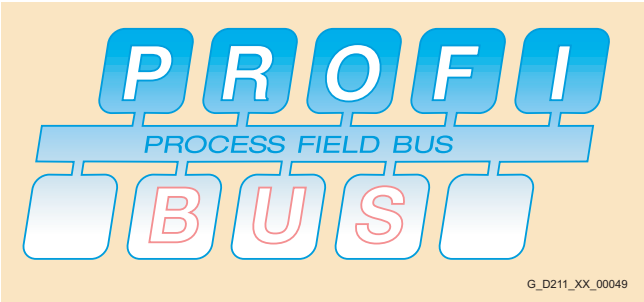
Utilization category 4 is the most important category for highly dynamic and highly complex Motion Control tasks. This application category describes in detail the master/slave relationship between the controller and the drives which are connected to each other over PROFIBUS and PROFINET.

The DSC (Dynamic Servo Control) function significantly improves the dynamic response and stiffness of the position control circuit by minimizing the dead times which usually occur for speed setpoint interfaces with an additional, relatively simple feedback network in the drive. The position control circuit is closed in the drive which permits very fast position control cycles (e.g. 125 µs for SINAMICS S) and thus limits dead times exclusively to the control behavior.

In SINAMICS S the drive interface has been implemented according to the PROFIdrive profile V4 and Utilization Categories 1 to 4 (Category 4 with and without DSC) and is referred to below as the PROFIdrive interface.

PROFIBUS

Overview



What is PROFIBUS?

PROFIBUS is the most successful open fieldbus used for automation technology which can be used for a wide range of applications. Standardization to IEC 61158 / EN 50170 provides future protection for your investment.

PROFIBUS defines the technical and functional features of a serial fieldbus system with which distributed programmable field controllers of the low-end (sensor/actuator level) to mid performance range (cell level) can be networked.

The demands of users for an open, vendor-independent communication system resulted in the specification and standardization of the PROFIBUS protocol.

Multi-vendor installations

Through the conformity and interoperability test performed by the test laboratories authorized by the PROFIBUS user organization (PNO) and the certification of the devices by the PNO, the user can rest assured that quality and functionality are also ensured for multi-vendor installations.

PROFIBUS variants

PROFIBUS FMS (Fieldbus Message Specification) – The universal solution for communication tasks on the field and cell level of the industrial communication hierarchy.

PROFIBUS PA (Process Automation) – The variant for applications in process automation. PROFIBUS PA uses the intrinsically safe transmission technology specified in IEC 61158-2.

PROFIBUS DP (Distributed Peripherals) – This variant, which is optimized for speed, is tailored especially for the communication of automation systems with distributed I/O stations and drives. The outstanding features of PROFIBUS DP are

- Very short response times
- High interference immunity

PROFIBUS replaces cost-intensive parallel signal transmission with 24 V and the measured value transmission with 0/4 mA to 20 mA technology.

PROFIBUS and SINAMICS

SINAMICS uses the PROFIBUS protocol PROFIBUS DP.

Design

Bus station

PROFIBUS DP distinguishes between two different master classes and one slave class:

Class 1 DP master

The DP master Class 1 is the central component in PROFIBUS DP. The central master station exchanges information with distributed stations (DP slaves) in a fixed, repeated message cycle.

Class 2 DP master

Devices of this type are used (programming, configuration or control devices) during start-up, for configuring the DP system, for diagnostics or controlling the plant during normal operation. A DP master Class 2 can be used, for example, to read the input, output, diagnostic and configuration data of the slaves.

DP slave

A DP slave is an I/O device which receives output information or setpoints from the DP master and sends input information, measured values or actual values to the DP master in response. A DP slave never sends data independently, it must always be prompted by the DP master.

The volume of input and output data depends on the device and can be up to 244 bytes per DP slave and transfer direction.

Function

Functions on PROFIBUS DP

The functional scope can differ between DP masters and DP slaves. The functional scope is different for DP-V0, DP-V1 and DP-V2.

DP-V0

The DP master functions (DP-V0) comprise of the functions "Configuration", "Parameter assignment", "Read diagnostic data", as well as "Cyclic reading of input data/actual values" and "Writing output data/setpoints".

DP-V1

The additional DP function expansions (DP-V1) make it possible to perform non-isochronous read and write functions, as well as processing cyclic data communication. This type of slave must be supplied with extensive parameterization data during start-up and normal operation. These acyclically transferred parameterization data are only rarely changed in comparison to the cyclic setpoints, actual values, and measured values, and are transferred at lower priority in parallel with the cyclic high-speed useful data transfer. Detailed diagnostic information can be transferred in the same way.

DP-V2

The extended DP master functions (DP-V2) mainly comprise functions for isochronous operation and direct data exchange between DP slaves.

Isochronous mode is implemented by means of a signal with a constant bus cycle for the bus system. This isochronous, constant cycle is sent by the DP master to all bus stations in the form of a global control message. The master and slaves can then synchronize their applications with this signal. The signal jitter between cycles is less than 1 µs.

The so-called publisher/subscriber model is used to implement direct slave-to-slave communication. Slaves declared as publishers make their input data/actual values and measured values available to other slaves, the subscribers, for reading. This is performed by sending the response message to the master as a broadcast. Slave-to-slave communication is therefore a cyclic process.

SINAMICS systems and PROFIBUS DP

SINAMICS S drives can operate only as DP slaves and support all communication functions, i.e. DP-V0, DP-V1 and DP-V2.

Overview

G_D211_XX_00050

PROFINET is the innovative and open Industrial Ethernet standard (IEC 61158) for industrial automation. With PROFINET, devices can be linked up from the field level through to the management level.

PROFINET enables system-wide communication, supports plant-wide engineering and applies IT standards right down to the field level. IT communication, data communication and cyclic process communication are combined on the basis of Industrial Ethernet.

Existing fieldbus systems such as PROFIBUS can be easily integrated without any modification of existing devices.

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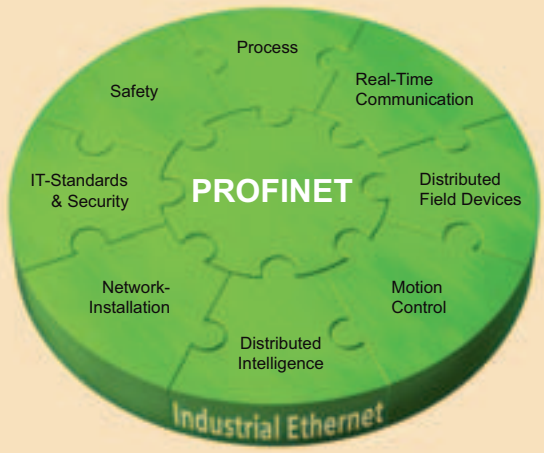
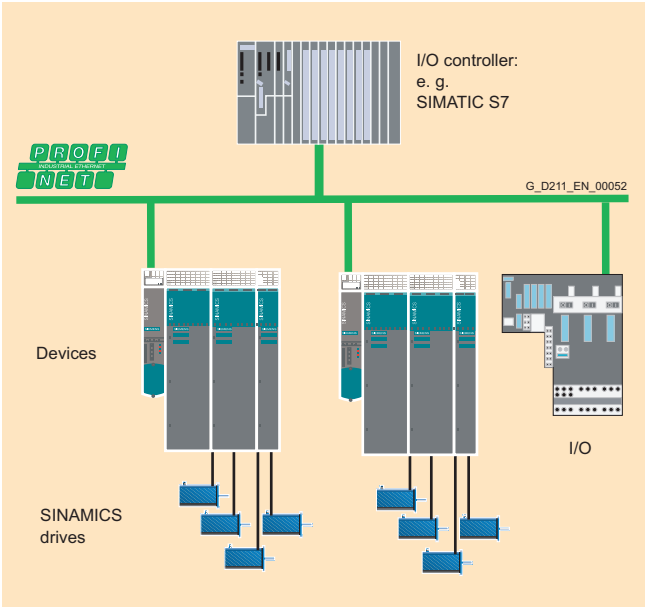


Design

PROFINET device concept

PROFINET distinguishes between the controller and devices assigned to it. These are initialized and parameterized by the controllers on power-up. The controller and its devices together constitute a PROFINET I/O system (compare master/slave system for PROFIBUS).

For PROFINET, cyclic communication between an I/O controller and its I/O devices is performed in the same way as for PROFIBUS over the process image. The process image is updated cyclically, depending on the requirements and device characteristic this takes place in real-time (RT, devices are typically distributed I/O devices) or isochronous real-time (IRT, devices are typically servo drives). In addition, PROFINET permits communication between controllers and devices of different I/O systems.



PROFINET IO with RT for simple standard drive applications

With typical cycle times of between 4 ms and 10 ms, PROFINET IO with RT offers the same performance characteristics as PROFIBUS as regards cyclic data transmission.

With this performance level, all standard drive applications belonging to PROFIdrive application categories 1 to 3 can be automated, i.e. those categories requiring the specification of speed, torque and current setpoints or target positions which do not need to be linked isochronously.

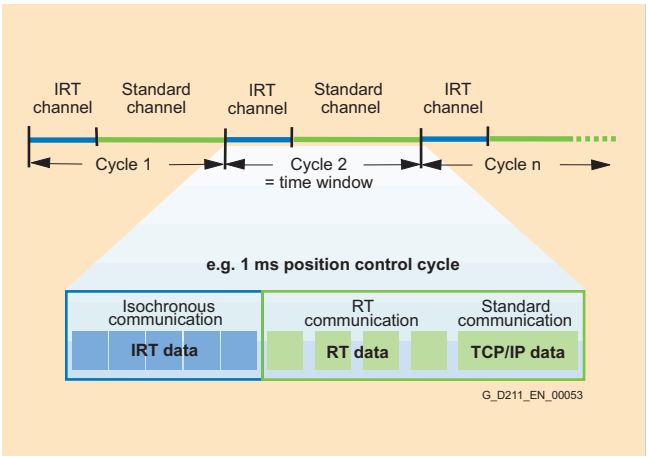
2

Design (continued)

PROFINET IO with IRT for Motion Control

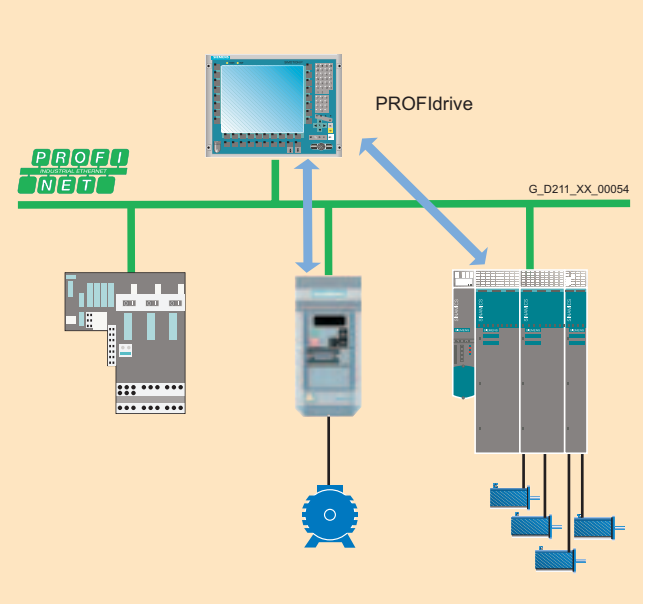
In this case, a Motion Control system (e.g. SIMOTION) controls or synchronizes axes using the PROFINET network. This requires cyclic, isochronous data exchange with the drives. PROFINET IO with IRT fulfils this requirement. The communication cycle is subdivided into different, time-specific channels for this purpose. The first channel is used for isochronous real-time communication (IRT), followed by real-time communication (RT) and standard TCP/IP communication. By configuring the application, e.g. synchronous operation of two axes, the IRT messages are determined implicitly and the corresponding configuration data are generated.

The optimum time sequence of the individual messages for each network section is calculated with a special algorithm which takes the topology into account. This permits a switch to forward the IRT messages without delay from the input port to the specified output port and then to the target device.



Transition from PROFIBUS to PROFINET

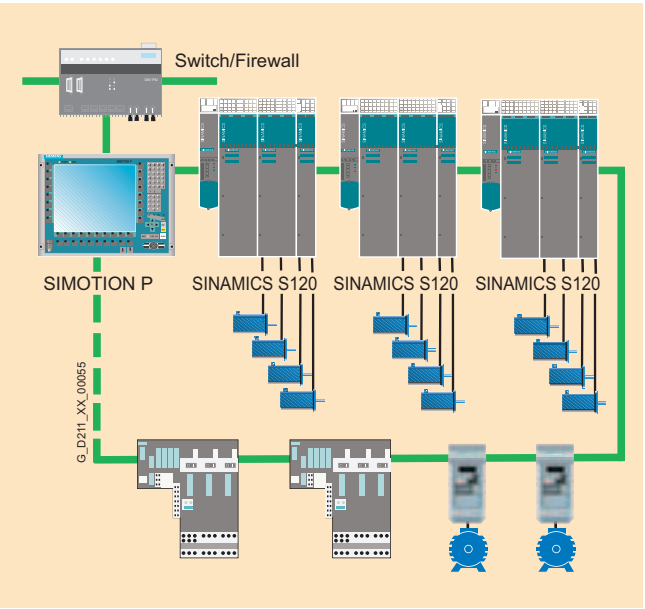
The functional interface between the controller and the SINAMICS drives for PROFINET and PROFIBUS is defined by the PROFIdrive drive profile V4 of PROFIBUS International. It is not necessary to change an application program for the transfer between PROFIBUS and PROFINET.



PROFINET with PROFIdrive

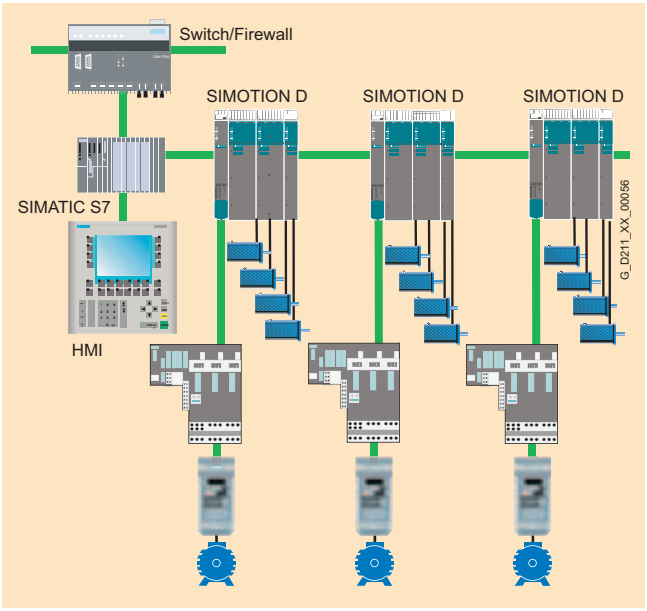
Motion Control concepts with PROFINET

With SINAMICS, PROFINET supports the implementation of different automation structures. Distributed drive-based Motion Control concepts (e.g. with SIMOTION D) or central architectures with a control (e.g. SIMOTION P) are supported in the same way as distributed automation solutions with modular automation components.



Central Motion Control architecture

Design (continued)



Distributed Motion Control architecture

PROFINET interface on SINAMICS

- SINAMICS S with a CU320 Control Unit and a CBE20 Communication Board
  The CU320 Control Unit on SINAMICS S is linked to the PROFINET IO network via the CBE20 Communication Board. The CBE20 Communication Board includes the PROFINET ASIC ERTEC400.
  - 4 ports with one RJ45 socket each
  - Integrated 4-port switch
  - 100 Mbit/s full duplex
  - PROFINET IO device
  - PROFINET IO with RT and IRT
  - TCP/IP communication to engineering
- SIMOTION D
  The SIMOTION D4x5 are linked to the PROFINET IO network via the CBE30 Communication Board. The CBE30 Communication Board includes the PROFINET ASIC ERTEC400.
  - 4 ports with one RJ45 socket each
  - Integrated 4-port switch
  - 100 Mbit/s full duplex
  - PROFINET IO controller
  - PROFINET IO with RT and IRT
  - Standard TCP/IP, UDP communication
  - PG/OP communication for connection of HMI and PG, IT communication

Function

Real-time communication with PROFINET IO

PROFINET uses standard TCP/IP for parameter assignment, configuration and diagnostics. Real-time communication for the transmission of process data is performed on the same line. PROFINET has the following real-time features:

- Real-time (RT)
  uses the option of prioritizing the communication stack of the stations. This permits high-performance data transmission with standard network components.
- Isochronous Real-Time (IRT)
  permits strict deterministic, cyclic data transmission with short response times and minimum jitter for high performance motion control applications. This feature is implemented with a special ASIC, the so-called ERTEC (Enhanced Real Time Ethernet Controller), in the corresponding interfaces (switch integrated into device) or network components (switch).

Automation with PROFINET

With these and other features PROFINET fulfills all automation requirements: Industry-compatible installation technology, real-time capability, deterministic responses, integration of distributed field devices, simple network administration and diagnostics, protection against unauthorized access, efficient vendor-independent engineering as well as isochronous motion control applications.

PROFINET relies on switch technology and has expanded this technology for real-time applications (IRT). This has the advantage that the network topology can be optimally utilized and adapted to the requirements of the machine. Collisions are prevented and an optimal data throughput is achieved.