

INTERNATIONAL STANDARD

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**Adjustable speed electrical power drive systems –
Part 7-304: Generic interface and use of profiles for power drive systems –
Mapping of profile type 4 to network technologies**

**Entraînements électriques de puissance à vitesse variable –
Partie 7-304: Interface générique et utilisation de profils pour les entraînements
électriques de puissance – Mise en correspondance du profil de type 4 avec les
technologies de réseaux**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ADJUSTABLE SPEED ELECTRICAL POWER DRIVE SYSTEMS –**Part 7-304: Generic interface and use of profiles for power drive systems – Mapping of profile type 4 to network technologies**

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International Standard IEC 61800-7-304 has been prepared by subcommittee SC 22G: Adjustable speed electric drive systems incorporating semiconductor power converters, of IEC technical committee TC 22: Power electronic systems and equipment.

This second edition cancels and replaces the first edition published in 2007. This edition constitutes a technical revision.

This edition includes the following significant technical change with respect to the previous edition: Update of mapping specification.

The text of this standard is based on the following documents:

FDIS	Report on voting
22G/314/FDIS	22G/329/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61800 series, under the general title *Adjustable speed electrical power drive systems*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,
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INTRODUCTION

The IEC 61800 series is intended to provide a common set of specifications for adjustable speed electrical power drive systems.

IEC 61800-7 specifies profiles for power drive systems (PDS) and their mapping to existing communication systems by use of a generic interface model.

IEC 61800-7 describes a generic interface between control systems and power drive systems. This interface can be embedded in the control system. The control system itself can also be located in the drive (sometimes known as "smart drive" or "intelligent drive").

A variety of physical interfaces is available (analogue and digital inputs and outputs, serial and parallel interfaces, fieldbuses and networks). Profiles based on specific physical interfaces are already defined for some application areas (e.g. motion control) and some device classes (e.g. standard drives, positioner). The implementations of the associated drivers and application programmers interfaces are proprietary and vary widely.

IEC 61800-7 defines a set of common drive control functions, parameters, and state machines or description of sequences of operation to be mapped to the drive profiles.

IEC 61800-7 provides a way to access functions and data of a drive that is independent of the used drive profile and communication interface. The objective is a common drive model with generic functions and objects suitable to be mapped on different communication interfaces. This makes it possible to provide common implementations of motion control (or velocity control or drive control applications) in controllers without any specific knowledge of the drive implementation.

There are several reasons to define a generic interface:

For a drive device manufacturer

- less effort to support system integrators;
- less effort to describe drive functions because of common terminology;
- the selection of drives does not depend on availability of specific support;

For a control device manufacturer

- no influence of bus technology;
- easy device integration;
- independent of a drive supplier;

For a system integrator

- less integration effort for devices;
- only one understandable way of modeling;
- independent of bus technology.

Much effort is needed to design a motion control application with several different drives and a specific control system. The tasks to implement the system software and to understand the functional description of the individual components may exhaust the project resources. In some cases, the drives do not share the same physical interface. Some control devices just support a single interface which will not be supported by a specific drive. On the other hand, the functions and data structures are often specified with incompatibilities. This requires the system integrator to write special interfaces for the application software and this should not be his responsibility.

Some applications need device exchangeability or integration of new devices in an existing configuration. They are faced with different incompatible solutions. The efforts to adapt a solution to a drive profile and to manufacturer specific extensions may be unacceptable. This will reduce the degree of freedom to select a device best suited for this application to the selection of the unit which will be available for a specific physical interface and supported by the controller.

IEC 61800-7-1 is divided into a generic part and several annexes as shown in Figure 1. The drive profile types for CiA® 402¹, CIP Motion™², PROFIdrive³ and SERCOS®⁴ are mapped to the generic interface in the corresponding annex. The annexes have been submitted by open international network or fieldbus organizations which are responsible for the content of the related annex and use of the related trade marks.

The different profile types 1, 2, 3 and 4 are specified in IEC 61800-7-201, IEC 61800-7-202, IEC 61800-7-203 and IEC 61800-7-204.

This part of IEC 61800-7 specifies how the profile type 4 (SERCOS®) is mapped to the network technologies SERCOS® and EtherCAT®⁵.

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IEC 61800-7-301, IEC 61800-7-302 and IEC 61800-7-303 specify how the profile types 1, 2 and 3 are mapped to different network technologies (such as CANopen⁶, CC-Link IE⁷ Field Network, EPA⁸, EtherCAT⁹, Ethernet Powerlink⁹, DeviceNet¹⁰, ControlNet¹¹, EtherNet/IP¹², PROFIBUS¹³ and PROFINET¹⁴).

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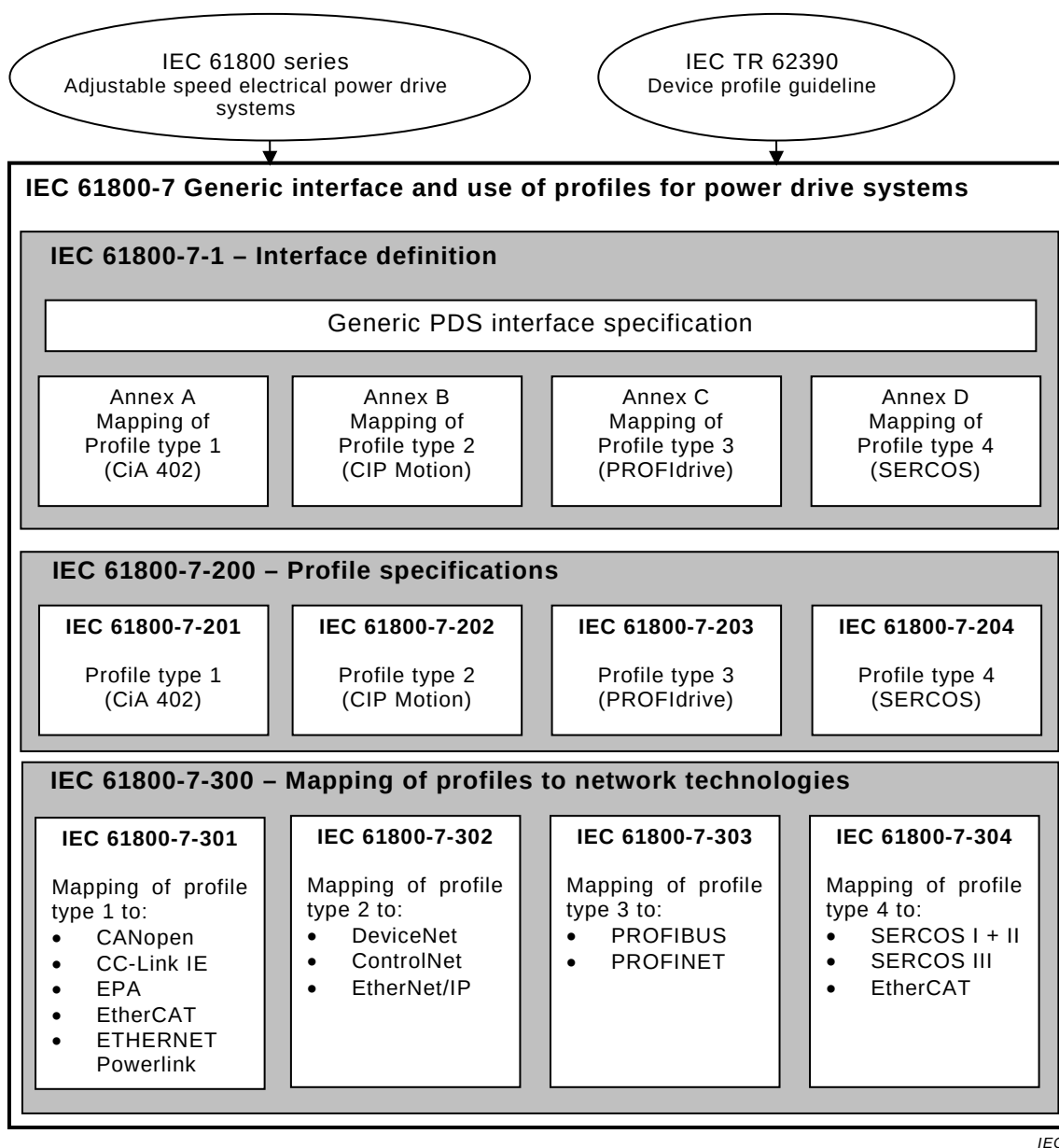


Figure 1 – Structure of IEC 61800-7

ADJUSTABLE SPEED ELECTRICAL POWER DRIVE SYSTEMS –

Part 7-304: Generic interface and use of profiles for power drive systems – Mapping of profile type 4 to network technologies

1 Scope

This part of IEC 61800 specifies the mapping of the profile type 4 (SERCOS) specified in IEC 61800-7-204 onto different network technologies.

- SERCOS I / II, see Clause 5,
- SERCOS III, see Clause 6,
- EtherCAT, see Clause 7.

The functions specified in this part of IEC 61800-7 are not intended to ensure functional safety. This requires additional measures according to the relevant standards, agreements and laws.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61158-2, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 61158-4-16, *Industrial communication networks – Fieldbus specifications – Part 4-16: Data-link layer protocol specification – Type 16 elements*

IEC 61158-5-16, *Industrial communication networks – Fieldbus specifications – Part 5-16: Application layer service definition – Type 16 elements*

IEC 61491:2002, *Electrical equipment of industrial machines – Serial data link for real-time communication between controls and drives*

IEC 61784-1, *Industrial communication networks – Profiles – Part 1: Fieldbus profiles*

IEC 61784-2, *Industrial communication networks – Profiles – Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC 8802-3*

IEC 61800-7-204:2015, *Adjustable speed electrical power drive systems – Part 7-204: Generic interface and use of profiles for power drive systems – Profile type 4 specification*

ISO/IEC/IEEE 8802-3:2014, *Standard for Ethernet*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply

3.1.1**acknowledge telegram****AT**

telegram, in which each slave inserts its data

Note 1 to entry: The English abbreviation AT is also used in French.

3.1.2**algorithm**

completely determined finite sequence of operations by which the values of the output data can be calculated from the values of the input data

[SOURCE: IEC 61800-7-1:2015, 3.2.1]

3.1.3**application**

software functional element specific to the solution of a problem in industrial-process measurement and control

Note 1 to entry: An application may be distributed among resources, and may communicate with other applications.

[SOURCE: IEC 61800-7-1:2015, 3.2.2]

3.1.4**attribute**

property or characteristic of an entity

[SOURCE: IEC 61800-7-1:2015, 3.2.3]

3.1.5**class**

description of a set of objects that share the same attributes, operations, methods, relationships, and semantics

[SOURCE: IEC 61800-7-1:2015, 3.2.5]

3.1.6**commands**

set of commands from the application control program to the PDS to control the behavior of the PDS or functional elements of the PDS

Note 1 to entry: The behavior is reflected by states or operating modes.

Note 2 to entry: The different commands may be represented by one bit each.

[SOURCE: 61800-7-1:2015, 3.3.1.3]

3.1.7**communication cycle**

accumulation of all telegrams between two master synchronization telegrams

3.1.8**control**

purposeful action on or in a process to meet specified objectives

[SOURCE: 61800-7-1:2015, 3.2.6]

3.1.9

control device

control unit

physical unit that contains – in a module/subassembly or device – an application program to control the PDS

[SOURCE: 61800-7-1:2015, 3.2.7]

3.1.10

control word

two adjacent bytes inside the master data telegram containing commands for the addressed PDS

[SOURCE: IEC 61800-7-1:2015, 3.3.5.4, modified — The word "drive" is replaced by the word "PDS".]

3.1.11

cycle time

time span between two consecutive cyclically recurring events

3.1.12

cyclic communication

periodic exchange of telegrams

3.1.13

cyclic data

part of the message which does not change its meaning during cyclic operation of the interface

3.1.14

cyclic operation

devices in the communication network are addressed and queried one after the other at fixed, constant time intervals

3.1.15

data exchange

demand dependent, non cyclic transmission of information after request was sent by the master (service channel)

[SOURCE: 61800-7-1:2015, 3.3.5.7]

3.1.16

data type

set of values together with a set of permitted operations

[SOURCE: 61800-7-1:2015, 3.2.8]

3.1.17

device

field device

networked independent physical entity of an industrial automation system capable of performing specified functions in a particular context and delimited by its interfaces

[SOURCE: 61800-7-1:2015, 3.2.9]

3.1.18**device profile**

representation of a device in terms of its parameters, parameter assemblies and behavior according to a device model that describes the device's data and behavior as viewed through a network, independent from any network technology

[SOURCE: 61800-7-1:2015, 3.2.11]

3.1.19**fibre optic cable**

transmission medium for serial data transmission of optical signals

3.1.20**functional element**

entity of software or software combined with hardware, capable of accomplishing a specified function of a device

Note 1 to entry: A functional element has an interface, associations to other functional elements and functions.

Note 2 to entry: A functional element can be made out of function block(s), object(s) or parameter list(s).

[SOURCE: 61800-7-1:2015, 3.2.13]

3.1.21**identification number****IDN**

designation of operating data under which a data block is preserved with its attribute, name, unit, minimum and maximum input values, and the data

Note 1 to entry: The English abbreviation IDN is also used in French.

3.1.22**input data**

data transferred from an external source into a device, resource or functional element

[SOURCE: 61800-7-1:2015, 3.2.14]

3.1.23**interface**

shared boundary between two entities defined by functional characteristics, signal characteristics, or other characteristics as appropriate

[SOURCE: 61800-7-1:2015, 3.2.15]

3.1.24**line**

network topology in which the transmission medium is routed from station to station in the form of a line

Note 1 to entry: The information is transmitted in one direction from the master down to the last slave in the line, and then flows back to the master via all the slaves in the reverse order (CP16/3, CP12).

3.1.25**master**

node, which assigns the other nodes the right to transmit

3.1.26

master data telegram

MDT

telegram, in which the master inserts its data

Note 1 to entry: The English abbreviation MDT is also used in French.

3.1.27

master synchronization telegram

MST

telegram, or part of a telegram, in which the master inserts a time synchronization signal

Note 1 to entry: The English abbreviation MST is also used in French.

3.1.28

model

mathematical or physical representation of a system or a process, based with sufficient precision upon known laws, identification or specified suppositions

[SOURCE: 61800-7-1:2015, 3.2.17]

3.1.29

non-cyclic transmission

non-periodic exchange of data at the request of the master

3.1.30

operating cycle

period of the control loop within the PDS or the control unit

3.1.31

operating mode

characterization of the way and the extent to which the human operator intervenes in the control equipment

[SOURCE: 61800-7-1:2015, 3.2.18]

3.1.32

output data

data originating in a device, resource or functional element and transferred from them to external systems

[SOURCE: 61800-7-1:2015, 3.2.19]

3.1.33

parameter

data element that represents device information that can be read from or written to a device, for example through the network or a local HMI

Note 1 to entry: A parameter is typically characterized by a parameter name, data type and access direction.

[SOURCE: IEC 61800-7-1:2015, 3.2.20]

3.1.34

PDS enable

command to close the feedback loop(s)

3.1.35

PDS on

command that the power stage can be activated

**3.1.36
profile**

representation of a PDS interface in terms of its parameters, parameter assemblies and behavior according to a communication profile and a device profile

[SOURCE: IEC 61800-7-1:2015, 3.2.21, modified – Note 1 to entry is deleted.]

**3.1.37
protocol**

convention about the data formats, time sequences, and error correction in the data exchange of communication systems

**3.1.38
ring
ring structure**

network topology in which the transmission medium is routed from station to station in the form of a ring.

Note 1 to entry: The information is transmitted only in one direction (CP16/1, CP16/2) or in both directions (CP16/3)

**3.1.39
slave**

node, which is assigned the right to transmit by the master

**3.1.40
status**

set of information from the PDS to the application control program reflecting the state or mode of the PDS or a functional element of the PDS

Note 1 to entry: The different status information may be coded with one bit each.

**3.1.41
status word**

two adjacent bytes inside the PDS telegram containing status information

**3.1.42
telegram
message
dataset****3.1.43
topology**

physical network architecture with respect to the connection between the stations of the communication system

**3.1.44
transmission medium**

collective term for the real form of the physical connection between the stations of a communication network

Note 1 to entry: For instance, fibre optic cable can be used.

**3.1.45
type**

hardware or software element which specifies the common attributes shared by all instances of the type

[SOURCE: IEC 61800-7-1:2015, 3.2.23]

3.2 Abbreviated terms

ADR	address of a PDS. PDS address is ADR [$1 \leq \text{ADR} \leq 511$]
AT	acknowledge telegram
C1D	class 1 diagnostic
C2D	class 2 diagnostic
C3D	class 3 diagnostic
IDN	identification number
I/O	input/output
K	number of data records in the MDT (see also M)
k	time sequence of data records in the MDT, labelled as $k = 1$ to K
M	number of PDSs in one network (see also K)
m	time sequence of the ATs, labelled as $m = 1$ to M
MDT	master data telegram
MST	master sync telegram
NC	numerical control (also control unit or controller)
PDS	power drive system
PLC	programmable logic controller without a motion control command set
RT	real-time
SERCOS	SErial Real time COmmunication System
t_3	command value valid time
t_4	feedback acquisition capture point
t_5	maximum producer processing time
t_{11}	maximum consumer activation time
t_{MTSG}	command value processing time
t_{Ncyc}	control unit cycle time
t_{Pcyc}	producer cycle time
t_{Rcyc}	PDS control loop cycle time
t_{Scyc}	communication cycle time
UC	unified communication

4 General

This mapping defines among others the mapping to CP16/1 (SERCOS I), which has been previously specified in IEC 61491:2002 and it is incorporated in this standard as well as in the IEC 61158 and IEC 61784 communication standard families, while specifying the mapping of the SERCOS drive profile to the communication profiles CP16/2 (SERCOS II), CP16/3 (SERCOS III) and CP12 (EtherCAT).

In this part of IEC 61800-7, the mapping of the SERCOS drive profile (IEC 61800-7-204) to the CPF16 (SERCOS I, II and III) and CP12 (EtherCAT) communication profiles is described.

The SERCOS CP16/1 and CP16/2 interface use fibre optic transmission between control units and PDSs. As a result, interference is eliminated.

The SERCOS CP16/3 and EtherCAT CP12 use Ethernet data transmission instead. It may be realised either using 100BASE-TX (wire) or 100BASE-FX (fibre optic) depending upon the immunity performance needs.

5 Mapping to CP16/1 (SERCOS I) and CP16/2 (SERCOS II)

5.1 Reference to communication standards

CP16/1 and CP16/2 are specified in the IEC 61158 series and are referenced in IEC 61784-1. The detailed references are listed in IEC 61784-1, which shows also the differences between these two communication profiles.

5.2 Overview

Table 1 summarises the major features of CP16/1 and CP16/2.

Table 1 – CP16/1 and CP16/2 feature summary

Feature	CP16/1	CP16/2
Topology	Ring	Same as CP16/1
Data flow	From the master to the 1 st slave, then to the next one, and so on until the last slave, then to the master (simplex communication between each participant)	Same as CP16/1
Communication medium	Fibre optic	Same as CP16/1
Transmission rate	2 Mbit/s or 4 Mbit/s	Same as CP16/1 In addition: 8 or 16 Mbit/s
Transmission rate setting	Manual setting (e.g. using a switch)	Same as CP16/1 In addition: Automatic baud rate recognition
Cycle time t_{Scyc}	62,5 μs , 125 μs , 250 μs , 500 μs , and up to 65 ms by steps of 250 μs .	Same as CP16/1
Number of slaves	Up to 254	Same as CP16/1
Device address ADR	$1 \leq \text{ADR} \leq 254$	Same as CP16/1
Synchronisation telegram	MST	Same as CP16/1
Slave telegrams	1 AT per PDS	Same as CP16/1
Master telegram	1 MDT	Same as CP16/1
Telegram order within a cycle	Compulsory: MST – ATs – MDT	Same as CP16/1
Non cyclic communication	Service channel (SVC): 2 bytes are reserved for each slave within AT and MDT	Same as CP16/1 In addition: It shall be possible to configure each slave for 4, 6, or 8 bytes within SVC
Initialization	Automatic at power-up ($t_{\text{Scyc}} \geq 1 \text{ ms}$) 4 intermediate communication phases (CP0 to CP3) before reaching normal operation (CP4)	Same as CP16/1
File transfer	Using the service channel	Same as CP16/1 In addition: Communication phases (CP5 and CP6) for file transfer

The exact number of PDSs which can be serviced per communication network depends on the cycle time, the selected data volume, and the transmission rate. The number of PDSs per control unit can also be expanded by using several networks. Table 2 shows some examples that are valid under normal operating conditions. The spare time is available for transmitting other data (e.g. communication with PLC-like I/Os) or as a safety margin to be used for later application developments.

Table 2 – Number of PDSs per network (examples)

Communication profile	Transmission rate	Cycle time	Data record to each PDS	Data record from each PDS	Number of PDSs	Data rate (service channel) per PDS	Spare time
CP16/1 and 16/2	2 Mbit/s	2 ms	32 byte	32 byte	8	8 kbit/s (2 bytes)	390 μ s
CP16/1 and 16/2	4 Mbit/s	1 ms	32 byte	32 byte	8	16 kbit/s (2 bytes)	125 μ s
CP 16/2	8 Mbit/s	1 ms	36 byte	36 byte	15	32 kbit/s (4 bytes)	208 μ s
CP 16/2	16 Mbit/s	500 μ s	36 byte	36 byte	14	128 kbit/s (8 bytes)	113 μ s
CP 16/2	16 Mbit/s	2 ms	16 byte	16 byte	112	8 kbit/s (2 bytes)	330 μ s

IEC 61800-7-204 standardises the formats and scaling factors for operation data exchange between control units and PDS devices. During initialization, the operation of the interface is configured according to the performance characteristics of the control unit and the PDSs. Therefore, the velocity and/or position control is implemented by either the PDS or the control unit.

The control unit is capable of synchronizing all connected PDSs by way of cyclic data exchange for command and feedback values, including exact equidistant timing and synchronization of gated measurements and command values. Communication cycle times may be selected between 62,5 μ s, 125 μ s, 250 μ s or any integer multiple of 250 μ s.

In addition, the control panel of the control unit can be used to display and input PDS-specific data, parameters and diagnostic information which are available via an asynchronous service channel and standardised data records.

Command and feedback values in short or long words can be transmitted between the control unit and each PDS in both directions. Optional data (e.g. parameters, diagnostic texts) are transmitted in segments during every cycle. This data can be requested individually by the control unit. Errors in command and feedback values are corrected automatically through cyclic communication. The last valid command and feedback values are used until the next cycle. Two consecutive erroneous transmissions will cause the PDSs to halt.

With the SERCOS interface, a control unit may serve one or several networks, depending on the requirements. One example is shown in Figure 2.

The connection of the control unit on a network is called a master. This master shall direct and control any communication within one network.

A slave is the connection between one or more PDSs and the network, or between an I/O station and the network. As shown in Figure 2, a group of PDSs such as several PDSs and I/Os may be clustered and tied into the network through a single connection depending on application. Individual participants shall be connected to each other via transmission segments that shall meet the requirements of CP16/1 (SERCOS I) or CP16/2 (SERCOS II).

The information exchanged in such a network depends greatly on the distribution of tasks between the control unit, the PDSs and I/O stations. Direct exchange of information takes place between the control unit on one side, the PDSs and I/O stations on the other side.

Interoperability between the communication profiles shall be as shown in Table 3.

Table 3 – Communication Profile Interoperability within a network

Master	Slave complying to CP16/1	Slave complying to CP16/2
CP16/1	Yes	Yes
CP16/2	Yes ^a	Yes
^a With a CP16/2 master, CP16/1 slaves are interoperable only at 2 Mbit/s or 4 Mbit/s.		

The CP16/1 and CP16/2 interfaces shall allow for synchronization during cyclic data transmission as required by the SERCOS profile (see IEC 61800-7-204). It means that the operating cycle of the control unit can be synchronized with the communication cycle and operating cycle of the PDS so that beats between individual cycles can be prevented and the dead times in the control loops can be reduced to a minimum. It also implies that new command signals become active concurrently in all PDSs and that all PDSs take measurements at the same time, so that they can be sent back to the control unit as feedback values. This requires that the transmission cycles be strictly equidistant.

The data in the control loops need to be precise and punctual. Untimely data are of no value. When a transmission error is discovered, the communication cycle continues and the old data or an estimated value may be used for one communication cycle. To repeat the transmission with old data (for the purpose of correcting the error) is meaningless, since during the next communication cycle (e.g. 1 ms later), new command data will be transmitted. In the event of repeated transmission errors, a predetermined reaction, such as halting the system, shall ensue.

The non-cyclic transmission mode does not fulfil strict real-time requirements. The correctness of the data is acknowledged or is secured by repeating the transmission.

5.3 Physical layer and topology

The SERCOS CP16/1 (SERCOS I) and CP16/2 (SERCOS II) interface shall use fibre optic transmission between control units and PDSs, as specified in IEC 61158-2.

Communication topology shall be a ring, as shown in Figure 2.

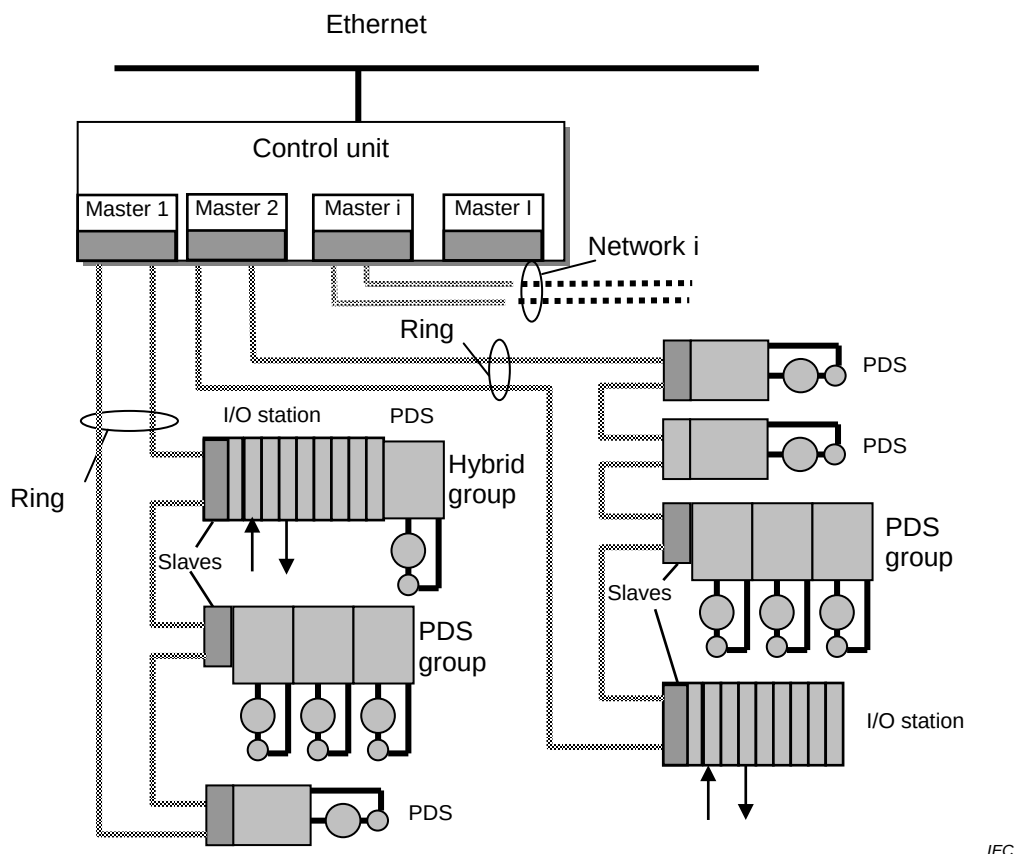


Figure 2 – Topology

5.4 Synchronization mechanism

5.4.1 General

If, on a machine, several PDSs are moving in co-ordination with one control (contouring control), certain technical requirements shall be fulfilled in order to achieve a deviation-less trajectory:

- process the command values;
- capture the feedback values;
- synchronize different cycle times and fine interpolators in the PDSs.

CP16/1 and CP16/2 shall provide for the cyclic transmission of following telegrams, in that order, as can be shown in Figure 3:

- 1) The master shall send a synchronization telegram that is called MST to all slaves.
- 2) Each slave shall send its data telegram that is called AT back to the master.
- 3) The master shall send its master data telegram that is called MDT to all slaves.

During network initialization, the master shall transmit to each slave all parameters that determine the time slot and the data content of these telegrams. In that way each slave shall be able to transmit its AT and to read its part of the MDT without interfering with the others slaves.

The communication cycle time shall be selected among the following values:

62,5 μ s, 125 μ s, and then 250 μ s to 65 ms in 250 μ s increments.

Subclause 5.11.5 defines 3 granularities.

5.4.2 Handling of command and feedback values

The MST shall not only control the access to the network, but also assist in orienting the processing within the PDSs. Designs shall be possible in which the PDSs provide feedback values for the control unit. These values shall be captured in all affected PDSs simultaneously. The capture point indicated by t_4 referenced to the end of the MST shall be stored in the PDSs as an IDN. The PDSs shall already have a default time interval t_5 stored as an IDN. This time interval shall indicate the minimum amount of time needed between the capture point t_4 and the end of the next MST, to allow the PDS to process the captured feedback value for the following AT.

t_3 shall be defined as another parameter. This parameter shall indicate after which time interval, counting from the end of the MST, the PDS is allowed to access the new command values transmitted in the MDT. The master stores t_3 as an IDN in the PDSs. In order to determine t_3 , the parameter t_{MTSG} (command value proceeding time) shall be stored in the PDSs as an IDN. This parameter shall describe the minimum time required by the slave to process the new command value(s) for the PDS(s) after the MDT.

Figure 3 illustrates these time intervals.

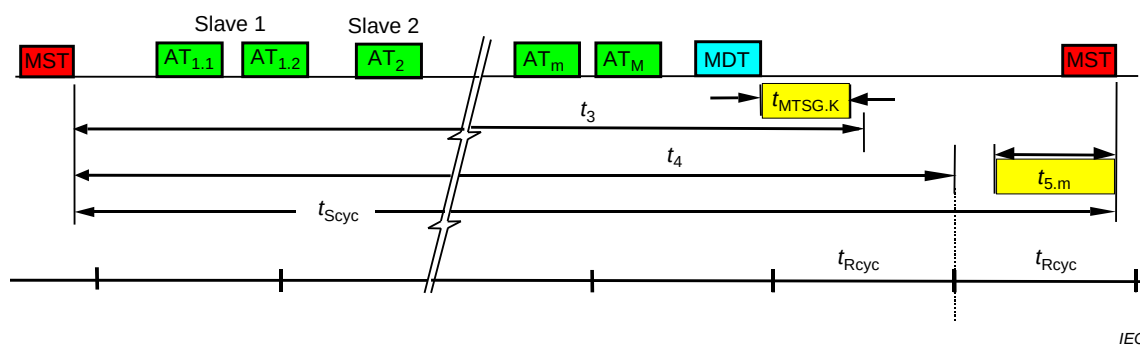


Figure 3 – Validity of command values and feedback acquisition time in the PDSs

Synchronization of the control loops in the PDSs

The feedback values shall be captured in time t_4 in the PDS, and the control loops (cycle time t_{Rcyc}) shall be synchronized in the PDS at that time (see Figure 3 and Figure 4).

The PDSs need a certain time to activate a newly received command value in the control loop. The command values available at time t_3 shall be activated in the control loop to the next time t_4 . If the time between t_3 and t_4 is too small, then the command values shall only be activated in the next cycle at time t_4 .

If a PDS is programmed to detect that times t_3 and t_4 are in a critical range, it is recommended that the PDS generates a diagnostic message. The PDSs manufacturers shall document the dependencies of time t_3 and t_4 and the diagnostic message in the PDS's manual.

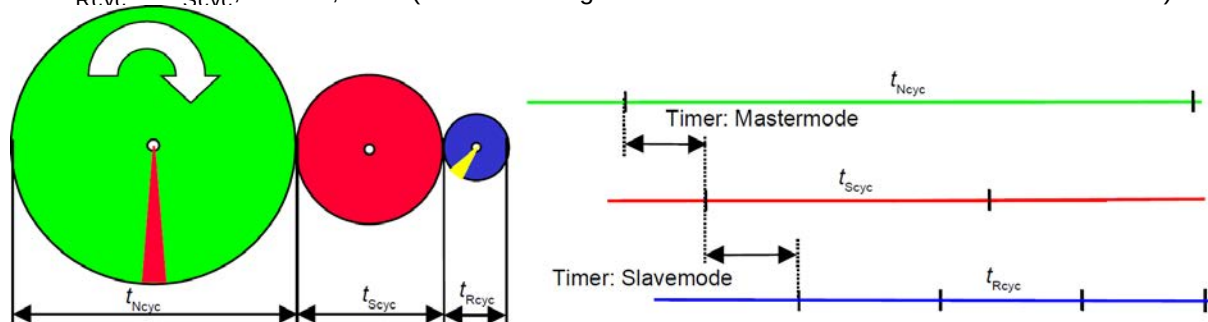
The cycle time within the control unit and the PDSs shall be as specified below.

- The cycle time during which the control unit shall provide new command values for the PDSs shall be called t_{Ncyc} . The operating cycle inside of the control unit shall be an integer multiple of the communication cycle time. If the operating cycle time is n times longer than the communication cycle time, the same calculated values shall be transmitted n times in consecutive telegrams:

$t_{Ncyc} = n \times t_{Scyc}$, $n = 1, 2, \dots$ (n is an integer that is not related to the abbreviations)

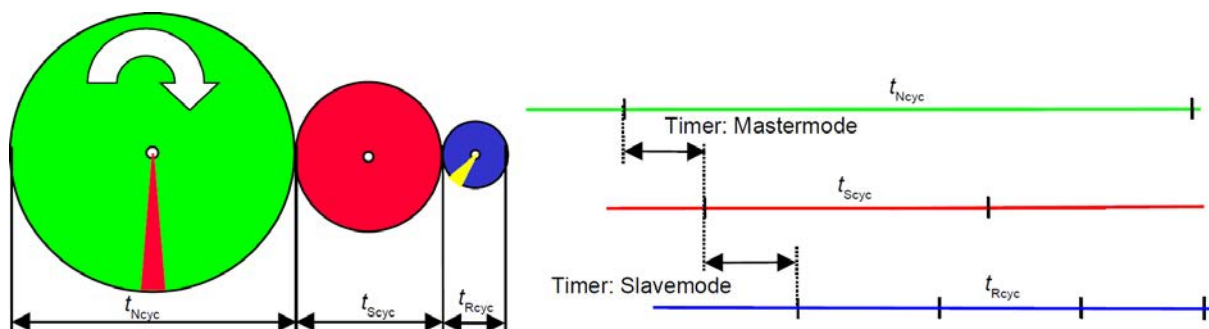
- b) Micro-processor controlled PDS shall have operating algorithms that are oriented to the data transmission. The cycle time during which the PDS shall perform its control algorithm shall be called t_{Rcyc} . It shall be an integer divider of the communication cycle time, and shall be in phase with the synchronization telegram. If the PDS cycle time is z times shorter than the communication cycle time, intermediate values for command values shall be interpolated inside the PDS:

$z \times t_{Rcyc} = t_{Scyc}$, $z = 1, 2, \dots$ (z is an integer that is not related to the abbreviations)



IEC

Figure 4 shows graphically how t_{Ncyc} and t_{Rcyc} relate to t_{Scyc} .



IEC

Figure 4 – Synchronization of cycle times

5.4.3 Position loop with fine interpolator

At time t_4 , the fine interpolator shall provide the corresponding received position command value to the position control. At the same time, the last received position command value shall be provided to the fine interpolator (see Figure 5). The fine interpolator shall calculate the differences in the position command values (Δ_{pos}) for all steps (position control cycles). The differences in the position command values shall be calculated with:

- the ratio of the NC-cycle time and the PDS cycle time,
- the position command values,
- (optionally) the velocity and acceleration,
- type and order of fine interpolation.

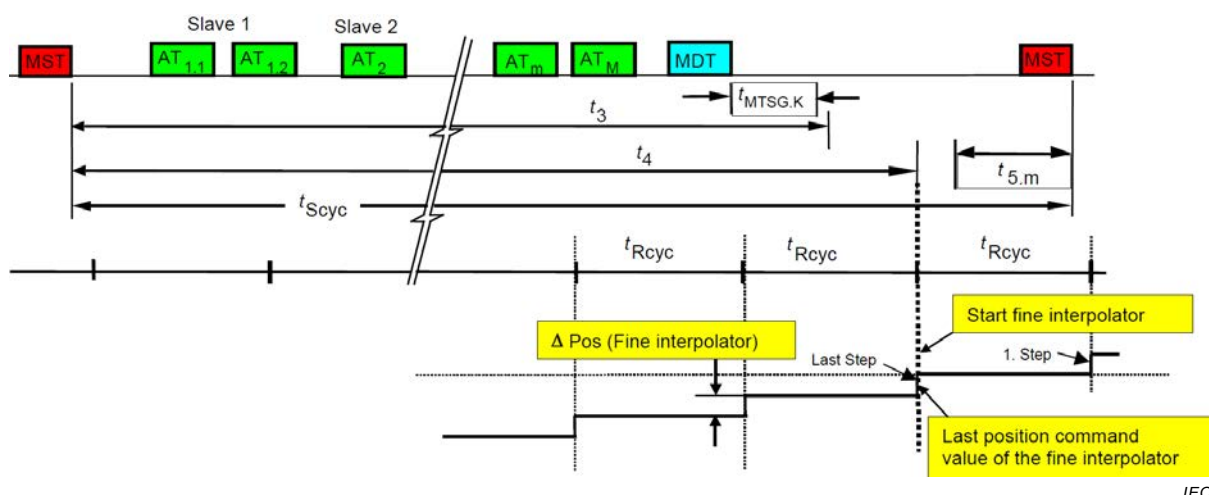


Figure 5 – Synchronization of the control loops and the fine interpolator

5.5 Telegram contents

5.5.1 General

IEC 61800-7-204:2015, Clause 7 specifies a comprehensive list of transmittable data (as well as procedure commands) which are predetermined in the SERCOS profile. IEC 61158-5-16 specifies additional, communication-specific transmittable data. The reader will find there also a description of individual data. In this subclause, an overview is presented, organised according to the mode of transmission (cyclic/non-cyclic) and the mode of operation. Table 4 gives an example of typical data that is transmitted cyclically.

During a communication cycle, one control word shall be sent from the control unit to each PDS and a status word shall be sent back from each PDS to the control unit. Configurable operation data shall be transmitted bidirectionally between the control unit and each PDS cyclically. Table 4 gives some typical representations. The three operating modes are shown with command and feedback values.

Table 4 – Typical operation data for cyclic transmission

	Position data	Velocity data	Torque data
Control unit to PDS	Control word		
	Position command value	Velocity command value	Torque command value
	Additive position command value	Additive velocity command value	Additive torque command value
PDS to control unit	Status word		
	Position feedback value 1	Velocity feedback value	Torque feedback value
	Position feedback value 2		

Both the control word and the status word are organised into a PDS-related and a transmit-related part. Non-cyclic transmissions are controlled by means of the transmit-related part (control/acknowledge steps). Each control and status word reserves two additional real-time bits for cyclic transmission.

The PDS-related part of the control word contains the desired modes of operation. This part is also used to transmit the commands for “PDS on” and “PDS enable”. The PDS-related part of the status word transmits grouped messages of errors and warnings which are divided into three classes. This part also issues messages indicating whether the PDS is ready to operate or ready for power-up.

Table 5 demonstrates that, typically, a much broader spectrum of data is exchanged by the non-cyclic transmission mode. However, this exchange is much slower than the cyclic mode.

Table 5 – Typical data for non-cyclic transmission

Data related to the operating mode of the SERCOS interface		
Position data	Velocity data	Torque data
Positive limit value	Positive limit value	Positive limit value
Negative limit value	Negative limit value	Negative limit value
	Bipolar limit value	Bipolar limit value
Polarities	Polarities	Polarities
Reference distance 1	Homing velocity	
Reference distance 2		
Reversal clearance		
Position switch points 1 to 16		
Probe value 1 or 2 positive edge		
Probe value 1 or 2 negative edge		

As mentioned earlier, a component (PDS or control unit) which is equipped with the SERCOS interface does not need to support all possible data and procedure commands included in this specification. The system provides lists of data and procedure commands which are applicable for the appropriate component. These lists can be read from a PDS by means of the control unit, thus providing all necessary information concerning that particular PDS.

The data to be transmitted and the sequence shall be determined during initialization.

Finally, during initialization, it is useful to transmit scaling data as a group. In this way, the data formats used by the internal operating algorithms of the PDS will be recalculated and changed in accordance with the specifications of SERCOS interface.

5.5.2 Data block

The SERCOS interface is not just a data transmission system. It provides a large number of data and procedure commands which can be used for the operation of machines and their control units and PDSs.

All data, procedure commands and all supplementary information are summarised in a data block which contains a name, attribute, units, minimum and maximum input values as well as the data itself. See IEC 61800-7-204:2015, Clause 12.

Access to the data or to the supplementary information is only possible via an identification number (IDN). There are 2^{16} IDNs available. The range from 0 to 32 767 is reserved for standard data which are defined by the SERCOS interface.

There will always be special applications for which none of the generally defined parameters apply. IDNs 32 768 to 65 535 are reserved for product specific data which can be defined by the manufacturers of control units and PDSs. No general compatibility can exist for these data and procedure commands.

5.5.3 Communication function group telegrams

The telegram contents of the configurable data records shall be determined either by the standard or application telegrams. This determination takes place in the telegram type parameter. For the structure of telegrams, refer to 5.5.4 and 5.5.5.

All feedback values which are contained in the AT for cyclic data shall be updated with valid data every cycle during CP4. In the MDT, the command values to be transmitted cyclically shall remain valid in CP4 depending on the operation mode.

When a standard telegram is chosen (see Table 6), operation data and the associated sequence in the configurable data record of the AT, as well as the MDT, shall be defined for a given PDS.

Table 6 – IDN for choice and parameterisation of telegrams

IDN	Description
S-0-0015	Telegram type

5.5.4 Standard telegrams

5.5.4.1 Standard telegram-0

No cyclic data shall be exchanged between the control unit and the PDS in a standard telegram-0. Only the fixed data record shall be defined. Data exchange shall take place through the service channel. Its structure is shown in Table 7.

Table 7 – Structure of standard telegram-0

Data record	Data field	Content	IDN	Length (byte)
MDT	–	–	–	0
AT	–	–	–	0

5.5.4.2 Standard telegram-1

Standard telegram-1 shall support the torque control operation mode in the PDS. Its structure is shown in Table 8.

Table 8 – Structure of standard telegram-1

Data record	Data field	Content	IDN	Length (byte)
MDT	1	Torque command value-	S-0-0080	2
AT	1	–	–	0

5.5.4.3 Standard telegram-2

Standard telegram-2 shall support the velocity control operation mode in the PDS. Its structure is shown in Table 9. The position feedback acquisition and the closing of the position loop shall take place in the control unit.

Table 9 – Structure of standard telegram-2

Data record	Data field	Content	IDN	Length (byte)
MDT	1	Velocity command value	S-0-0036	4
AT	1	Velocity feedback value	S-0-0040	4

5.5.4.4 Standard telegram-3

Standard telegram-3 shall support the velocity control operation mode in the PDS. Its structure is shown in Table 10. The position feedback acquisition shall take place in the PDS. The position loop shall be closed in the control unit.

Table 10 – Structure of standard telegram-3

Data record	Data field	Content	IDN	Length (byte)
MDT	1	Velocity command value	S-0-0036	4
AT	1	Position feedback value 1 or Position feedback value 2 (The content of the data field 1 of the AT depends on the telegram type parameter (S-0-0015)).	S-0-0051 or S-0-0053	4

5.5.4.5 Standard telegram-4

Standard telegram-4 shall support the position control operation mode in the PDS. Its structure is shown in Table 11. The position feedback acquisition shall take place in the PDS as well as the closing of the position loop.

Table 11 – Structure of standard telegram-4

Data record	Data field	Content	IDN	Length (byte)
MDT	1	Position command value	S-0-0047	4
AT	1	Position feedback value 1 or Position feedback value 2 (The content of the data field 1 of the AT depends on the telegram type parameter (S-0-0015)).	S-0-0051 or S-0-0053	4

5.5.4.6 Standard telegram-5

Standard telegram-5 shall support the velocity and position control operation mode in the PDS. Its structure is shown in Table 12. Switching modes between velocity and position control shall also be possible by means of standard telegram-5.

Table 12 – Structure of standard telegram-5

Data record	Data field	Content	IDN	Length (byte)
MDT	1	Position command value	S-0-0047	4
	2	Velocity command value	S-0-0036	4
AT	1	Position feedback value 1 or Position feedback value 2 (The content of the data field 1 of the AT depends on the telegram type parameter (S-0-0015)).	S-0-0051 or S-0-0053	4
	2	Velocity feedback value	S-0-0040	4

5.5.4.7 Standard telegram-6

Standard telegram-6 shall support the velocity control operation mode in the PDS. Its structure is shown in Table 13. The position feedback acquisition and the closing of the position loop shall take place in the control unit.

Table 13 – Structure of standard telegram-6

Data record	Data field	Content	IDN	Length (byte)
MDT	1	Velocity command value	S-0-0036	4
AT	1	–	–	0

5.5.5 Application telegrams

5.5.5.1 Configuration of the MDT

The length of the “configurable data record” in the MDT shall be limited by the “length of the configurable data record in the MDT” (S-0-0186). Cyclic data shall be assigned to the data fields in the configurable data record by means of the sequence of IDNs given in the configuration list of the MDT (S-0-0024).

Configured cyclic data shall always be transmitted in sequential data fields beginning with data field 1. No empty data fields are allowed in the MDT. Necessary IDN for the configuration of application telegrams MDT are listed in Table 14.

Table 14 – IDN for configuration of MDT

IDN	Description
S-0-0015	Telegram type
S-0-0024	Configuration list of MDT
S-0-0188	IDN–list of configurable data in the MDT
S-0-0186	Length of the configurable data record in the MDT

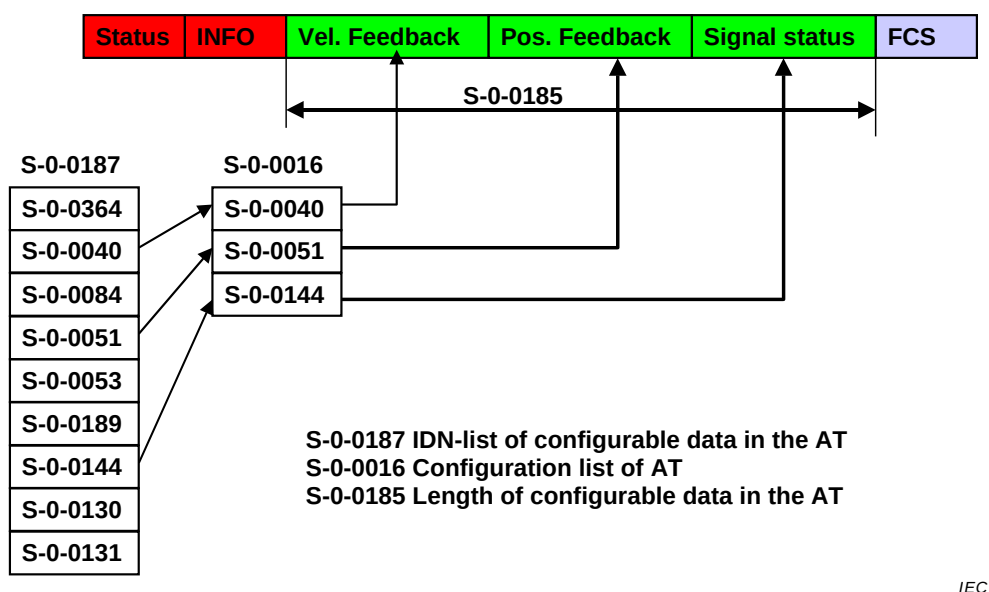
5.5.5.2 Configuration of the AT

The length of the “configurable data record” of the AT shall be limited by the “length of the configurable data record in the AT” (S-0-0185). Cyclic data shall be assigned to the data fields in the configurable data record by means of the sequence of IDNs given in the configuration list of the AT (S-0-0016).

Configured cyclic data shall always be transmitted in sequential data fields beginning with data field 1. No empty data fields are allowed in the AT. Necessary IDN for the configuration of application telegrams AT are listed in Table 15 and an example is shown in Figure 6.

Table 15 – IDN for configuration of AT

IDN	Description
S-0-0015	Telegram type
S-0-0016	Configuration list of AT
S-0-0187	IDN-list of configurable data in the AT
S-0-0185	Length of the configurable data record in the AT



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Figure 6 – AT configuration (example)

5.6 Non-cyclic data transfer

The non-cyclic data transfer shall be realised using the Service Channel (SVC).

5.7 Real-time bits

5.7.1 Functions of real time bits

Two real time bits shall be reserved in the control word of the MDT and in the status word of the AT, which may be used with special assignments, according to applications. Assignments shall be transmitted on demand via the service channel. The real-time bits are signals which shall indicate some selected status or event in the master or the PDSs. This status or event transmitted from the master to the PDS and vice versa shall be represented in real time. The parameters listed in Table 16 shall be available for the use of the real-time bits. Real-time control bits (in the control word of the MDT) shall be distinguished from real-time status bits (in the status word of the AT).

Table 16 – IDN for real-time bits

IDN	Description
S-0-0300	Real-time control bit 1
S-0-0302	Real-time control bit 2
S-0-0301	Allocation of real-time control bit 1
S-0-0303	Allocation of real-time control bit 2
S-0-0413	Bit number allocation of real-time control bit 1
S-0-0414	Bit number allocation of real-time control bit 2
S-0-0304	Real-time status bit 1
S-0-0306	Real-time status bit 2
S-0-0305	Allocation of real-time status bit 1
S-0-0307	Allocation of real-time status bit 2
S-0-0415	Bit number allocation of real-time status bit 1
S-0-0416	Bit number allocation of real-time status bit 2

A logic meaning may be assigned by the master to real-time bits by means of the assignment IDNs as specified in Table 17, depending on application.

Table 17 – Real-time bits assignment IDNs

Assignment IDNs	Logical value (IDN) assignment to
S-0-0301 and S-0-0413	Master's control word, real-time bit 1
S-0-0303 and S-0-0414	Master's control word, real-time bit 2
S-0-0305 and S-0-0415	Slave's status word, real-time bit 1
S-0-0307 and S-0-0416	Slave's status word, real-time bit 2

All logical assignments shall be IDNs of binary operation data (bits, switching signals). Any real-time bits activated through these assignments shall maintain their meaning until the master overwrites or erases them with S-0-0000 or until another IDN changes the logical assignment.

When there is a write access over the service channel to the operation data of an IDN which is assigned to a real-time control bit, the PDS shall generate the error: "operation data is write protected at this time" or "operation data is write protected, it is configured cyclically" (see Figure 7).

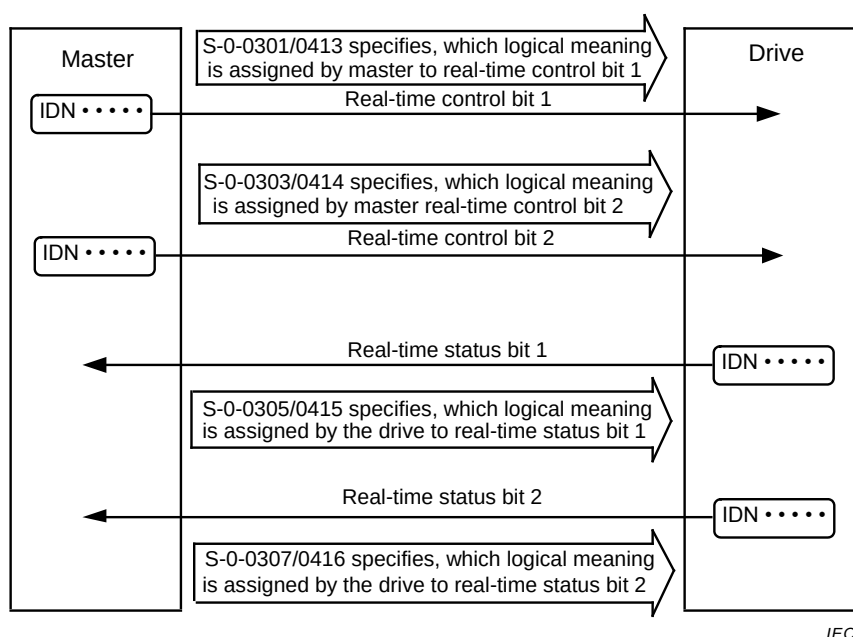


Figure 7 – Function of the real-time bits

5.7.2 Allocation of real-time bits

5.7.2.1 Allocation sequence of real-time control bits

When changing the allocation, the control shall first allocate the S-0-0000 to S-0-0301/0303. This shall invalidate the real-time control bit in the PDS. Afterwards, the control shall copy the new bit to the real-time control bit. After the new bit number (S-0-0413/0414) and the new IDN (S-0-0301/0303) have been allocated, the PDS shall evaluate the new real-time control bit.

5.7.2.2 Allocation sequence of real-time status bits

When the allocation is changed by IDN (S-0-0305/0307) and/or bit number (S-0-0415/0416), undefined states of real-time status bits occur. The control shall detect this and shall not evaluate the respective data. The PDS shall copy the new changed bit to the real-time status bit when it sets the BUSY bit = 0 at the latest.

5.7.3 Possible cases

5.7.3.1 Case 1

Allocation of an IDN $\neq 0$ to a real-time bit, when no other allocation to this real-time bit is active (see Figure 8).

The state of the real-time control bit shall be defined at the latest when element 7 of S-0-0301/0303 is written. The state of the real-time status bit shall be defined at the latest before the busy bit is reset.

NOTE Element 7 of an IDN is the operation data (see IEC 61800-7-204).

The evaluation of the real-time control bit shall be started in the PDS before the busy bit is reset. The evaluation of the real-time status bit shall not be started in the master before the PDS has reset the busy bit.

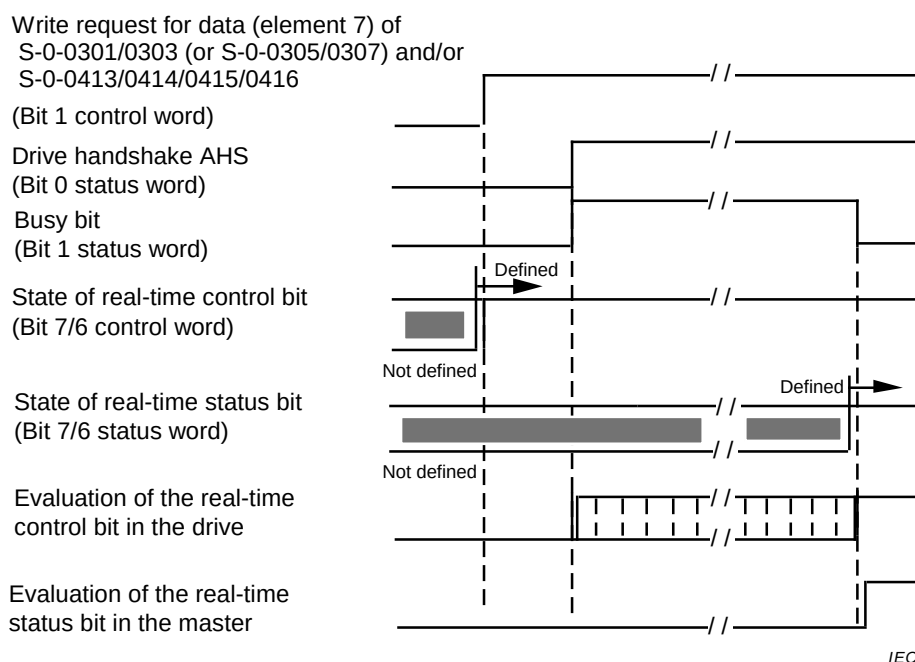


Figure 8 – Allocation of IDN ≠ 0 to the real-time bits

5.7.3.2 Case 2

Allocation of IDN = 0 to a real-time bit, when another allocation to this real-time bit is active (see Figure 9).

The state of the real-time control bit shall remain defined until the PDS resets the busy bit. The state of the real-time status bit shall be at least defined until the PDS sets the busy bit.

The evaluation of the real-time control bit shall be stopped before the PDS resets the busy bit. The evaluation of the real-time status bit shall be stopped in the control unit when element 7 is written.

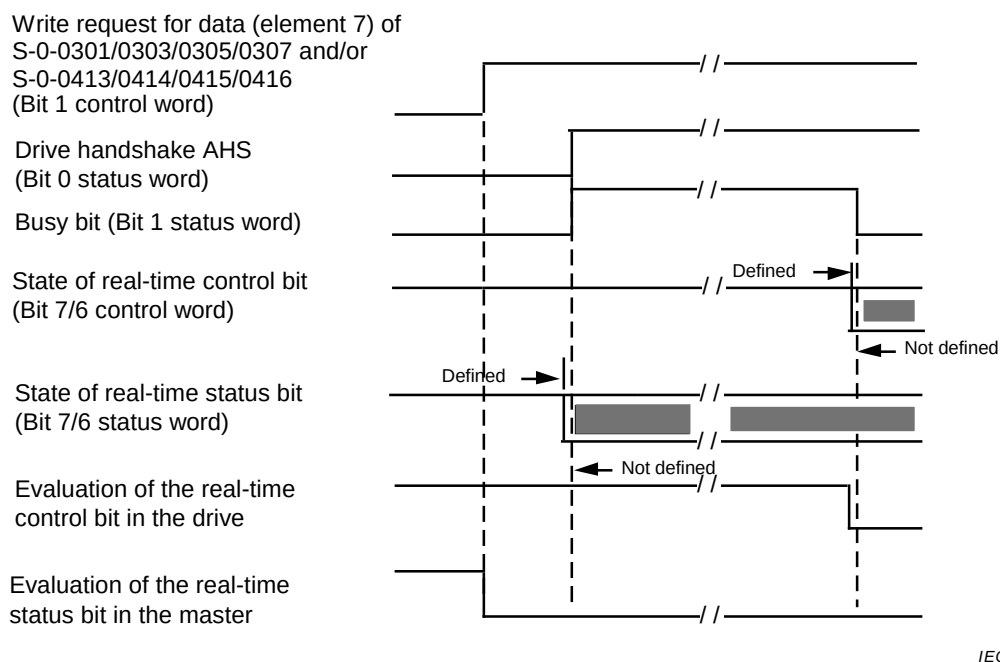


Figure 9 – Allocation of IDN = 0 to the real-time bits

5.7.3.3 Case 3

Allocation of an IDN ≠ 0 to a real-time bit, when another allocation to this real-time bit is active (see Figure 10)

The state of the old real-time control bit shall remain defined by the control unit until the write request for element 7 has been sent. When the busy bit is set by the PDS, the new real-time control bit shall be sent. The old real-time control bit shall be evaluated in the PDS until the busy bit is reset.

In the period from writing element 7 until the busy bit is reset, the control unit shall take care that the value of the transmitted real-time control bit does not lead to disallowed operation states or errors. Generally, this is only possible for “not active” real-time control bits, for which the value in the PDS has no meaning at this time.

The transition from an active real-time control bit to another shall only be allowed if the allocation via S-00000 is used (case 2, case 1). The control unit shall handle the switching according to these rules.

The state of the old real-time status bit shall not become undefined before the write request is received. The state of the new real-time status bit shall be defined before the busy bit is reset.

The evaluation of the real-time status bit in the control unit for the old allocation shall only be done until the write request for element 7 is sent. The new assignment shall not be evaluated before the PDS has reset the busy bit.

In the case of an error, the old allocation shall remain valid. In this case, the evaluation shall be allowed again as soon as the busy bit is reset.

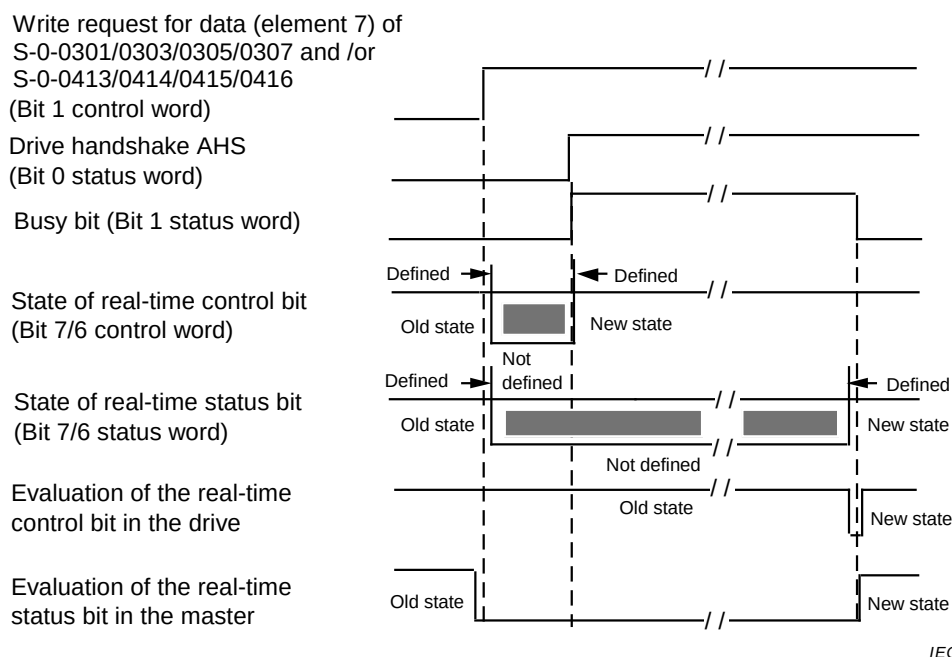


Figure 10 – Allocation of IDN ≠ 0 to the real-time bits

5.8 Signal control word and signal status word

Signals shall be transmitted in real-time from the control unit to the PDSs and vice versa by means of the signal control word and signal status word. For this purpose, the signal control word shall be integrated in the MDT and the signal status word in the AT. Bits in the signal control/status word shall be definable by means of the configuration list of the signal control/status word (see S-0-0027/0026) and of the "Bit number allocation list for signal control/status word" (see S-0-0329/0328), as shown in Table 18. If S-00329/0328 are not supported by the PDS, the bit 0 of the IDN shall be configured automatically.

Table 18 – IDN for configuring control and status words

IDN	Description
S-0-0145	Signal control word
S-0-0027	Configuration list for signal control word
S-0-0329	Bit number allocation list for signal control word
S-0-0144	Signal status word
S-0-0026	Configuration list for signal status word
S-0-0328	Bit number allocation list for signal status word

Figure 11 shows an example of signal status word configuration.

Bit number of signal status word:		0	1	2	3	4	5	6	
configured IDN (signal)		S-0-0403	S-0-0013	S-0-0000	S-0-0013	S-0-0013	S-0-0013	S-0-0330	
0E 00	20 00	93 01	0D 00	00 00	0D 00	0D 00	0D 00	4A 01	S-0-0026
configured bit number (signal)		0	5		9	0	4		
0E 00	20 00	00 00	05 00	00 00	09 00	00 00	04 00	00 00	S-0-0328
		Bit 0 of S-0-0403 Bit 5 of S-0-0013 Bit 9 of S-0-0013 Bit 0 of S-0-0013 Bit 4 of S-0-0013 Bit 0 of S-0-0330 ← Length of list →							
		Byte 3 and 4 indicate maximum data length available in the PDS. Example: Length = 32 bytes 0x0020							
		Byte 1 and 2 indicate length of programmed data in the PDS. Example: Length = 14 bytes 0x000E							

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Figure 11 – Configuration example of signal status word

5.9 Data container

Table 19 lists the IDN used for data containers.

Table 19 – Data containers IDN

IDN	Description
	Data container A
S-0-0360	MDT data container A1
S-0-0364	AT data container A1
S-0-0368	Data container A pointer
S-0-0362	MDT data container A list index
S-0-0366	AT data container A list index
S-0-0370	MDT data container configuration list
S-0-0371	AT data container configuration list
	Data container B
S-0-0361	MDT data container B
S-0-0365	AT data container B
S-0-0369	Data container B pointer
S-0-0363	MDT data container B list index
S-0-0367	AT data container B list index

Two data containers (A and B) shall be defined for the MDT and AT, serving as placeholders in the MDT and AT. The contents of the data containers shall be dynamically changeable by the control unit as necessary, or based upon the operation mode. Additionally, a data container pointer (S-0-0368 and (S-0-0369) is required for each of the containers, as well as a configuration list for the MDT and AT containers (S-0-0370, S-0-0371). Data containers shall be 4 bytes long. If the configured operation data is only 2 bytes long, it shall be placed in the lower part of the data container. In this case, the higher part shall not be used.

The data container pointers shall contain an 8-bit pointer that shall define what operation data will be placed in the data container. The pointer shall be the offset within the data container

configuration list (S-0-0370 or S-0-0371) from the start of the IDN list to the desired IDN. The control unit shall place the desired operation data in the MDT data container, while the PDS shall place the desired operation data in the AT data container.

The control unit shall enter, into the MDT data container configuration list, the IDN for the operation data that are to be sent via the MDT data container as needed from the control unit to the PDS.

The control unit shall enter, into the AT data container configuration list, the IDN for the operation data that are to be sent via the AT data container as needed from the PDS to the control unit.

The addressing IDNs (S-0-0368, S-0-0369) shall be configurable in the cyclic data of the MDT. Thereby, a switching of the operation data in the data containers within a communication cycle shall be possible (see Figure 12).

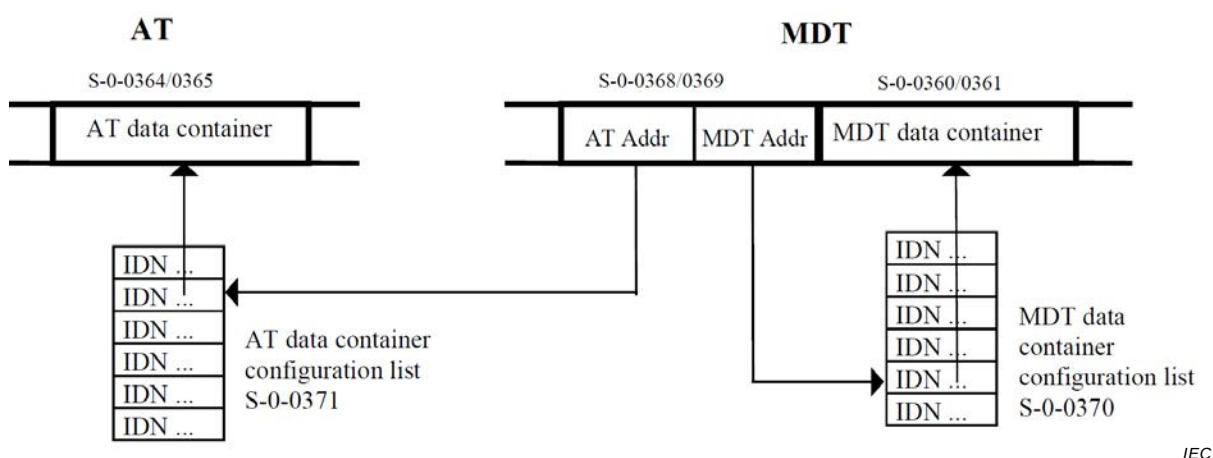


Figure 12 – Data container configuration without acknowledge (slave)

The addressing IDNs (S-0-0368, S-0-0369) shall also be configurable in the cyclic data of the AT. In this case, the addressing (acknowledgement) according to the contents of the data container shall be transmitted. The PDS shall generate the acknowledgement by copying the pointer of MDT to the pointer of AT. If the pointer of the data container is situated outside of the configuration list for the MDT or AT data container, or the data does not fit in the data container, the contents of the data container shall be invalid. The PDS shall set the pointer (acknowledgement) in the AT on 255. The data in MDT or AT data container shall be ignored (see Figure 13). The control unit shall compare the addressing (S-0-0368, S-0-0369) of MDT and AT. If the result is equal, it shall consider that the slave accepted the MDT data or wrote the requested data into the AT.

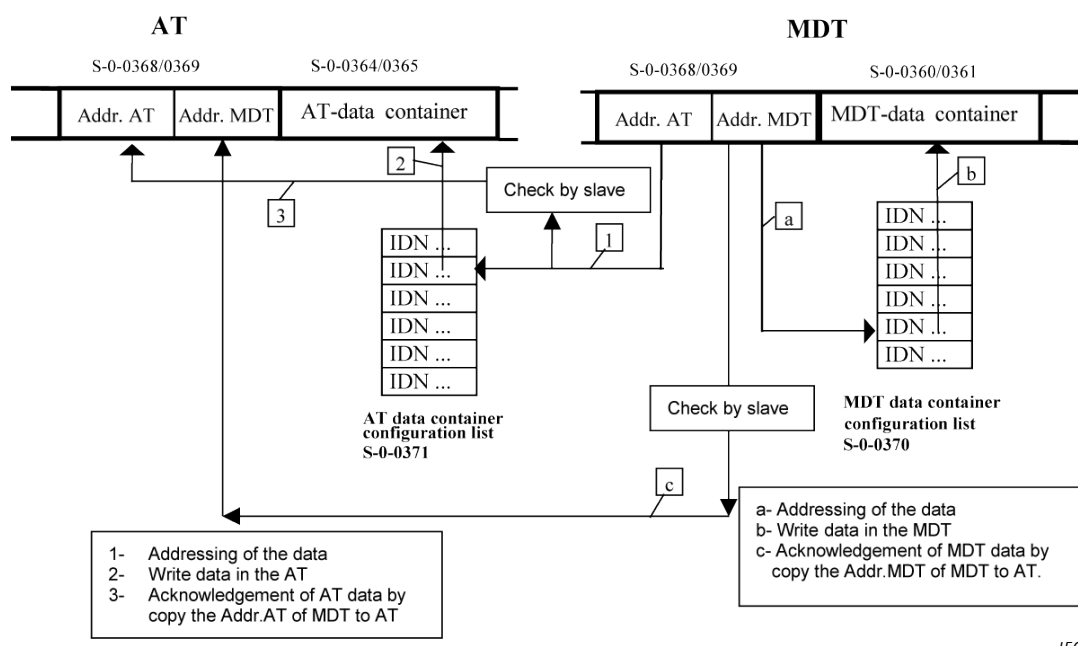


Figure 13 – Data container configuration with acknowledge (slave)

If, in the MDT-data container A or B, an IDN with a variable length (list) is configured, the corresponding data element of this list shall be addressed via the list index.

The list index of the MDT data container shall consist of a 16 bit address. Via index 65 535, the data container shall be defined invalid by the control unit.

The control unit shall set the addressed list element into the MDT data container.

The list index of MDT data container shall be configurable in the cyclic data of the MDT. Thereby, a switching of the list elements in the data container during a communication cycle shall be possible. During writing on the MDT data container with the list index, the length of the list shall not be changed.

The list index of MDT data container shall also be configurable into the cyclic data of the ATs. In this way, an acknowledgement of the MDT data container shall be possible. The PDS shall read the list index of MDT data container from the MDT and acknowledge it in the AT.

If the list index is situated outside of the list, the list index of MDT shall be set in the AT (acknowledgement) on value 65 535 and/or the pointer of data container in AT (acknowledgement) on value 255. All data in the MDT data container shall be ignored by the slave.

5.10 Drive shutdown functions

Error handling is based on the principle that drives shall always be equipped with monitoring functions to guarantee an automatic shut-down in situations that prevent a correct response to commands from the control unit (master).

Since the SERCOS interface provides for operation only in CP4, the drives shall respond by shutting down automatically when CPs other than CP4 are present in the MST.

Drives shall automatically shut-down where a communication error impairs their ability to guarantee their correct functioning. This is the case where MSTs or MDTs fail twice in succession during CP4 in a drive.

As described above, drives which are unable to respond properly shall shut-down themselves. This does not necessarily mean that the control unit shall respond with an interrupt and re initialization when telegram failures occur in CP4. Rather, there may be certain procedures stored in the control unit which can be executed before shut-down, depending on the error situation. These procedures shall be part of the control unit.

When the slave sets the “communication error” bit in the class 1 diagnostic (C1D, S-0-0011), then the diagnostic message, S-0-0095, can be used to read a character set string describing the error.

5.11 Communication classes

5.11.1 General

Communication classes in the SERCOS interface shall be provided for by the various manufacturers in order to simplify the interoperability of SERCOS interface components. All functions which affect the operation of the master or slaves shall be as defined under different application profiles.

The SERCOS communication shall be subdivided in 3 classes. By definition, the communication classes follow a hierarchical structure. This means that a higher communication class shall assume the requirements of a lower communication class. Each communication class shall contain a certain range of function groups and IDNs. An illustration of this procedure is shown in Figure 14.

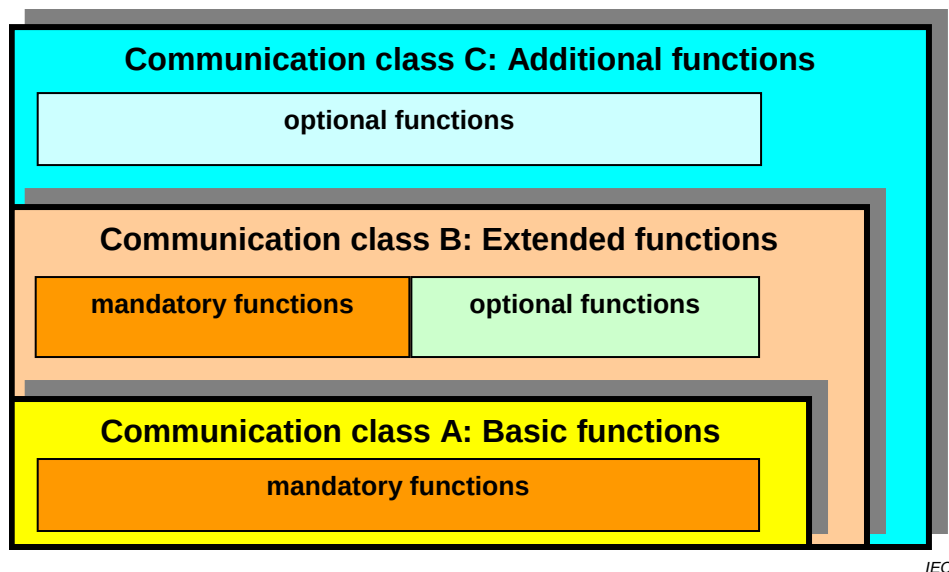


Figure 14 – Structure of communication classes

SERCOS interface components shall be described by supported:

- compliance classes (mandatory) one or more;
- additional functions (optional);
- communication cycle time (mandatory);
- transmission rate (mandatory).

NOTE Example for a PDS – class B position control – with following additional functions: position feedback (slave), positive stop PDS procedure, probing cycle: level 1 – communication cycle time: 0,5 ms – granularity 1 – transmission rate: 2 Mbit/s and 4 Mbit/s.

5.11.2 Communication class A

This class consists of all parameters that are required in order to allow the exchange of data in a way that is consistent with the SERCOS interface protocol. Each SERCOS interface component (e.g. PDS, control unit), shall support these parameters in order to close a SERCOS interface ring and operate fault free up to CP4, independent of the device.

Communication class A shall include the following basic communication-related functions:

- ring configuration;
 - timing (see Table 20);
 - standard telegram (see Table 21);
 - phase run-up (see Table 22);
- service channel protocol (see Table 23);
- communication error handling;
- information and diagnostics (see Table 24);
- status word (RT channel);
- control word (RT channel).

Table 20 – Ring configuration – Timing

IDN	Description	Capability	Comments
S-0-0001	Control unit cycle time (t_{Ncyc})	W	If the control unit uses a value different from S-0-0002, this shall be supported, as well as the Control Unit Synchronization Bit (control word, bit 10)
S-0-0002	Communication cycle time (t_{Scyc})	W	
S-0-0003	Shortest AT transmission starting time (t_{1min})	R	
S-0-0004	Transmit/receive transition time (t_{ATMT})	R	
S-0-0005	Maximum producer processing time (t_5)	R	
S-0-0006	AT transmission starting time (t_1)	W	
S-0-0007	Feedback acquisition capture point (t_4)	W	
S-0-0008	Command value valid time (t_3)	W	
S-0-0087	Transmit to transmit recovery time (t_{ATAT})	R	This parameter shall be provided even the slave does not support multiple devices. If the slave does not support multiple devices this parameter is set to "0".
S-0-0088	Receive to receive recovery time (t_{MTSY})	R	
S-0-0089	MDT transmission starting time (t_2)	W	
S-0-0090	Command value proceeding time (t_{MTSG})	R	
S-0-0096	Slave arrangement (SLKN)	R	

Table 21 – Ring configuration – Telegram configuration

IDN	Description	Capability	Comments
S-0-0009	Position of data record in MDT	W	
S-0-0010	Length of MDT	W	
S-0-0015	Telegram type	W	Standard telegrams only

Table 22 – Ring configuration – Phase run-up

IDN	Description	Capability	Comments
S-0-0021	IDN-list of invalid operation data for CP2	R	
S-0-0022	IDN-list of invalid operation data for CP3	R	
S-0-0028	MST error counter	R	
S-0-0029	MDT error counter	R	
S-0-0127	CP3 transition check	W	
S-0-0128	CP4 transition check	W	
RTChannel	Procedure command change	R	Status word, bit 5

Table 23 – Service channel protocol

IDN	Description	Capability	Comments
RTChannel	Service channel AT	R	Status word, bit 0 to 2
RTChannel	Service channel MDT	W	Control word, bit 0 to 5

Table 24 – Information & diagnostics

IDN	Description	Capability	Comments
S-0-0011	Class 1 diagnostic	R	Bit 12 for communication required only. Other bits defined by functional description of the profiles.
S-0-0012	Class 2 diagnostic	R	Required for function part of the profiles.
S-0-0013	Class 3 diagnostic	R	Required for function part of the profiles.
S-0-0014	Interface status	R	Bits 0 to 8 for communication required only.
S-0-0017	IDN-list of all operation data	R	
S-0-0025	IDN-list of all procedure commands	R	
S-0-0028	MST error counter	R	
S-0-0029	MDT error counter	R	
S-0-0030	Manufacturer version	R	
S-0-0095	Diagnostic message	R	
S-0-0096	Slave arrangement (SLKN)	R	
S-0-0099	Reset class 1 diagnostic	W	
S-0-0134	Master control word	R	
S-0-0135	PDS status word	R	
S-0-0143	SERCOS interface version	R	
RT channel	PDS shut down error	R	Status word, bit 13

The baud rates and cycle times to be supported shall be as defined by the detailed descriptions of the different profiles. The scanning of baud rates by the master should be deactivated, as this may interfere with the automatic baud rate recognition by the PDS which is an optional feature (communication class C).

The IDNs in Table 25 shall be written by the control unit in CP2. The control unit shall not rely on defaults or previously stored parameters. The PDS shall accept these parameters in CP 2. The control unit may or may not write additional parameters in CP2 depending upon configuration. The PDS shall accept all other parameters in CP3, as well.

Table 25 – Communication class A settings

IDN	Name	Access	Comment
S-0-0001	Control unit cycle time (t_{Ncyc})	CP2-W	Ring timing
S-0-0002	Communication cycle time (t_{Scyc})	CP2-W	Ring timing
S-0-0006	AT transmission starting time (t_1)	CP2-W	Ring timing
S-0-0007	Feedback acquisition capture point (t_4)	CP2-W	Ring timing
S-0-0008	Command value valid time (t_3)	CP2-W	Ring timing
S-0-0009	Position of data record in MDT	CP2-W	Telegram configuration
S-0-0015	Telegram type	CP2-W	Telegram configuration
S-0-0089	MDT transmission starting time (t_2)	CP2-W	Ring timing
S-0-0127	CP3 transition check	CP2-W	Phase switch

The parameter list S-0-0021 “IDN-list of invalid operation data for CP2” shall only reflect parameters from this table.

5.11.3 Communication class B (Extended functions)

Communication class B shall include:

- Communication class A with the following basic communication-related functions (see 5.11.2):
 - ring configuration (timing, standard telegram, phase run-up);
 - service channel protocol;
 - information & diagnostics;
 - status word (real-time channel);
 - control word (real-time channel).
- and the following extended communication functions:
 - ring configuration (telegram 7) (see Table 26);
 - extended information & diagnostics (see Table 27);
 - real-time control bits (see Table 28);
 - real-time status bits (see Table 29).

Table 26 – Ring configuration – Telegram configuration

IDN	Description	Capability	Comments
S-0-0016	Configuration list of AT	W	
S-0-0024	Configuration list of MDT	W	
S-0-0185	Length of the configurable data record in the AT	R	
S-0-0186	Length of the configurable data record in the MDT	R	
S-0-0187	IDN-list of configurable data in the AT	R	
S-0-0188	IDN-list of configurable data in the MDT	R	

Table 27 – Information & diagnostics

IDN	Description	Capability	Comments
S-0-0097	Mask class 2 diagnostic	W	
S-0-0098	Mask class 3 diagnostic	W	

Table 28 – Real-time control bits

IDN	Description	Capability	Comments
S-0-0300	Real-time control bit 1	R	
S-0-0301	Allocation of real-time control bit 1	W	
S-0-0302	Real-time control bit 2	R	
S-0-0303	Allocation of real-time control bit 2	W	

Table 29 – Real-time status bits

IDN	Description	Capability	Comments
S-0-0304	Real-time status bit 1	R	
S-0-0305	Allocation of real-time status bit 1	W	
S-0-0306	Real-time status bit 2	R	
S-0-0307	Allocation of real-time status bit 2	W	

The IDNs in Table 30 shall be written by the control unit in CP2. The control unit shall not rely on defaults or previously stored parameters. The PDS shall accept these parameters in CP 2. The control unit may or may not write additional parameters in CP2 depending upon configuration. The PDS shall accept all other parameters in CP3, as well.

Table 30 – Communication class B settings

IDN	Name	Access	Comment
S-0-0001	Control unit cycle time (t_{Ncyc})	CP2-W	Ring timing
S-0-0002	Communication cycle time (t_{Scyc})	CP2-W	Ring timing
S-0-0006	AT transmission starting time (t_1)	CP2-W	Ring timing
S-0-0007	Feedback acquisition capture point (t_4)	CP2-W	Ring timing
S-0-0008	Command value valid time (t_3)	CP2-W	Ring timing
S-0-0009	Position of data record in MDT	CP2-W	Telegram configuration
S-0-0015	Telegram type	CP2-W	Telegram configuration
S-0-0016	Configuration list of AT	CP2-W	Ring timing
S-0-0024	Configuration list of MDT	CP2-W	Ring timing
S-0-0089	MDT transmission starting time (t_2)	CP2-W	Ring timing
S-0-0127	CP3 transition check	CP2-W	Phase switch

The parameter list S-0-0021 “IDN-list of invalid operation data for CP2” shall only reflect parameters from this table.

5.11.4 Communication class C (Additional functions)

The communication class C shall contain:

- communication class B which includes (see 5.11.3):
 - communication class A with the following basic communication-related functions:
 - ring configuration (timing, standard telegram, phase run-up);
 - service channel protocol;
 - information & diagnostics;
 - status word (real-time channel);
 - control word (real-time channel).
 - and the following extended communication functions:
 - ring configuration (telegram 7);
 - extended information & diagnostics;
 - real-time control bits;
 - real-time status bits.
- and the following additional optional functions, such as:
 - automatic baud rate recognition;
 - physical order;
 - configurable real-time bits – signal control;
 - configurable real-time bits – signal status word;
 - data container – multiplex channel;
 - data container – list handling via multiplex channel;
 - list handling via service channel;
 - expanded service channel;
 - firmware up/download;
 - file transfer.

5.11.5 Communication cycle time granularity

For S-0-0002, the communication cycle time shall be preselected. t_{Scyc} shall be an integer multiple of the PDS cycle time and the control unit cycle time shall be an integer multiple of the communication cycle time. For good performance of the whole system, the cycle time should be as small as possible.

Three granularities shall be defined. In the absence of a granularity specification, the granularity 1 shall be assumed.

- granularity 1: 62,5 μ s, 125 μ s, 250 μ s, 500 μ s, and then 1 ms to 65 ms in 1 ms increments
- granularity 2: 62,5 μ s, 125 μ s, 250 μ s, and then 500 μ s to 65 ms in 500 μ s increments
- granularity 3: 62,5 μ s, 125 μ s, and then 250 μ s to 65 ms in 250 μ s increments

Implementation of the SERCOS interface shall support granularity 1 to insure inter-operability. Granularities 2 and 3 shall be regarded as optional enhancements.

6 Mapping to CP16/3 (SERCOS III)

6.1 Reference to communication standards

CP16/3 is specified in the IEC 61158 series and is referenced in IEC 61784-2. The detailed references are listed in IEC 61784-2.

6.2 Overview

CP16/3 (SERCOS III) performs in ways that are very similar to CP16/1 (SERCOS I) and CP16/2 (SERCOS II). See Clause 5. For this reason, 5.11.5 shows and specifies only in which ways this CP16/3 differs.

Table 31 summarises the major features of CP16/3.

Table 31 – CP16/3 features summary

Feature	CP16/3
Topology	Ring or line
Data flow	Double ring: From the master to the 1st slave, then to the next one, and so on until the last slave, then to the master. Simultaneously from the master to the last slave, then to the previous one, and so on until the 1st slave, then to the master. Each slave shall be able to read and modify the telegrams in both directions. Daisy chain: From the master to the 1st slave, then to the next one, and so on until the last slave, then back to the previous one, and so on until the 1st slave, then to the master. Each slave shall be able to read and modify the telegrams in both directions.
Direct communication between slaves	Supported
Communication medium	According to ISO/IEC/IEEE 8802-3 (Ethernet) Wire (100BASE-TX), or Fibre optic (100BASE-FX)
Transmission rate	100 Mbit/s
Cycle time t_{Scyc}	31,25 μs , 62,5 μs , 125 μs , 250 μs , 500 μs , and up to 65 ms by steps of 250 μs
Synchronization	Automatic transmission delay compensation
Number of slaves	Up to 511
Device address ADR	$1 \leq \text{ADR} \leq 511$
Synchronization telegram	MDT0
Slave telegrams	All slaves write into up to 4 ATs (AT0 to AT3)
Master telegrams	The master writes into up to 4 MDTs (MDT0 to MDT3)
Telegram order within a cycle	MDT0 to MDT3, AT0 to AT3
Non cyclic communication	Service channel (SVC): 4 bytes are reserved for each slave within AT and MDT
Support for other telegrams	Any Ethernet frame may be transmitted: – at each cycle in the UC channel, if the network has been configured for it; – at any time between the last slave in a line and other devices; – at any time between all devices before CP16/3 network initialization.
Initialization	Automatic at power-up ($t_{\text{Scyc}} \geq 1 \text{ ms}$) 4 intermediate communication phases (CP0 to CP3) before reaching normal operation (CP4)
File transfer	Using Service channel (SVC), SERCOS III IP services or using Ethernet frames, if the slave supports it
Hot plug	Supported
Redundancy	Supported If one communication fault (e.g. cable break) occurs in a ring topology, the network immediately behaves as two lines
Network monitoring	The whole network data is available at any point within the network

The exact number of PDSs which can be serviced per communication network depends on the communication cycle time, the selected data volume, and the transmission rate. The number of PDSs per control unit can also be expanded by using several networks.

6.3 Physical layer and topology

The SERCOS CP16/3 (SERCOS III) interface shall use Ethernet data transmission between control units and PDSs. It may be realised either using 100BASE-TX (wire) or 100BASE-FX (fibre optic) depending upon the application.

Communication topology shall be a line or a ring, as shown in Figure 15.

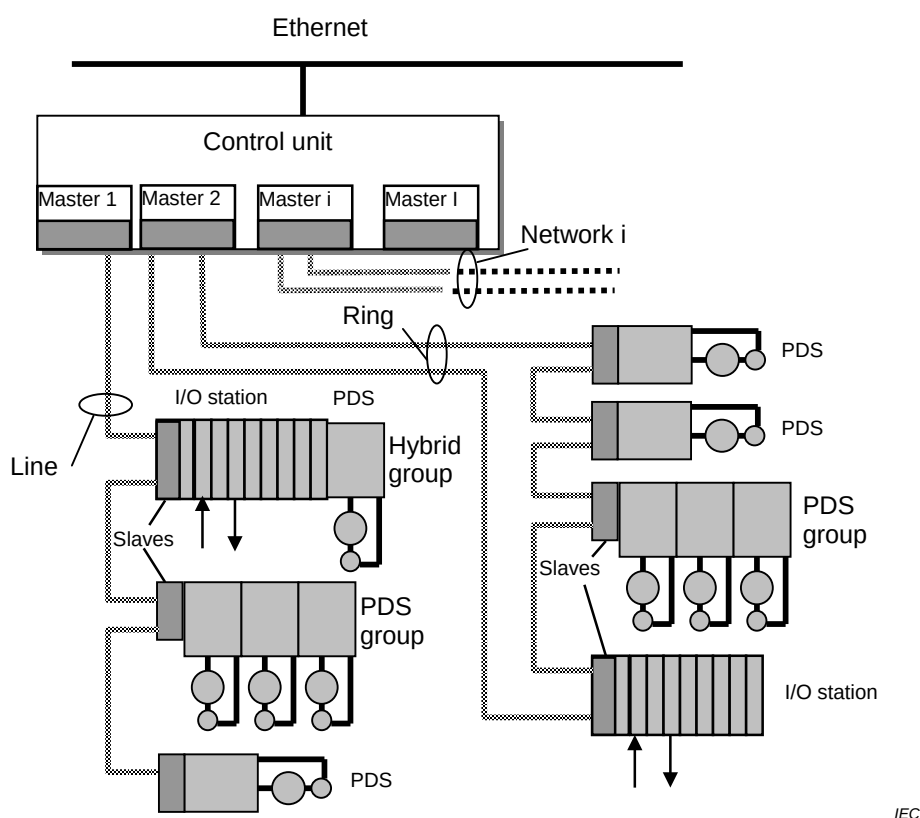


Figure 15 – Topology

The ring topology shall offer redundancy during communication. In case of a failure of one of the transmission lines (e.g., cable break, intentional connection removal), the master shall still be capable of communicating with all its slaves without interruption. Thus, reliability and availability of the network are enhanced.

Direct, real-time communication between slaves shall be fully supported. The master shall determine the participants in such direct communications.

For the logging on or off of participants, there shall be data fields (hot-plug fields) in the real-time telegrams. The procedures for logging on and off shall be as specified.

For monitoring purpose, the whole network real-time data content shall be available at any point within that network.

6.4 Synchronization mechanism and telegram content

Refer to 5.3 and Clause 5 (CP16/1 – SERCOS I and CP16/2 – SERCOS II).

CP16/3 (SERCOS III) synchronization differs only as follows (see Figure 16):

- a shorter cycle time (31,25 µs) shall be available in addition;
- the synchronization telegram (MST) shall be part of the master data telegram (MDT0);
- the slaves shall write their data into up to 4 telegrams (AT0 to AT4);
- the master shall write its data into up to 4 telegrams (MDT0 to MDT4).
- the network shall be configured depending upon application (either method 1 or method 2, see Figure 16) for providing a so-called UC channel, that is a time slot within each communication cycle, which may be placed either between the last MDT and AT0, or between the last AT and MDT0.

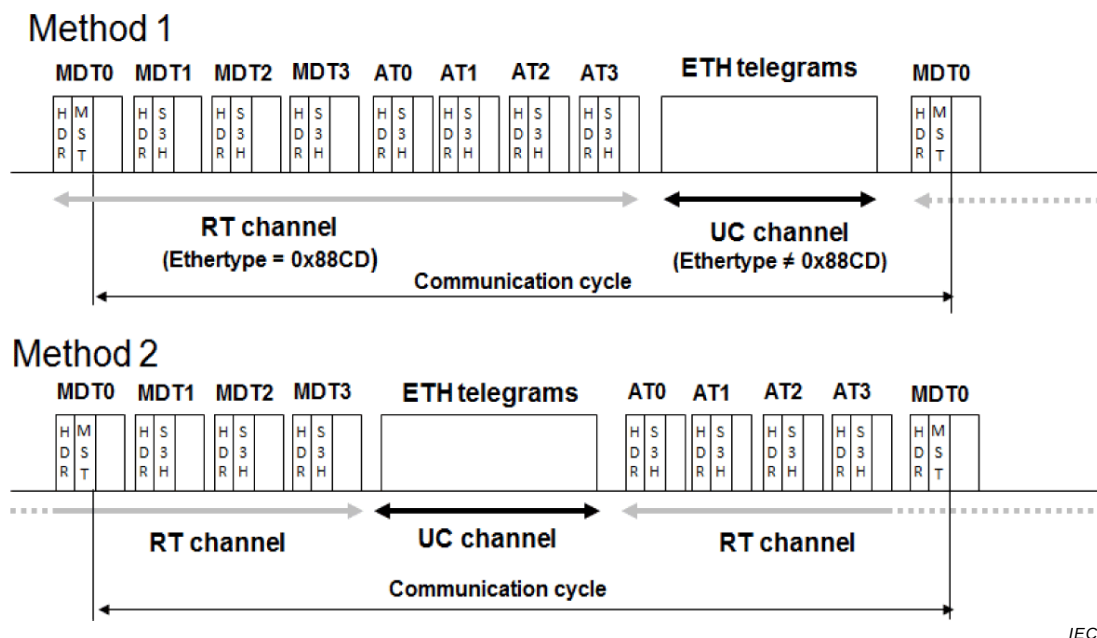


Figure 16 – Telegram sequence

6.5 Non-cyclic data transfer

Refer to Clause 5 (CP16/1 – SERCOS I and CP16/2 – SERCOS II).

CP16/3 (SERCOS III) non-cyclic data transfer differs only as follows.

- In the Service Channel (SVC), 4 bytes shall be reserved for each slave within ATs and MDTs.
- Non-cyclic data transfer shall be possible using the UC channel, if the slave supports TCP/UDP/IP communication.
- A communication cycle shall provide for non real-time communication (see UC channel in Figure 17) in addition to real-time communication the (RT-channel); the non real-time communication may optionally be used depending on application, and in that case, the master shall set the time-slot for the non real-time communication during initialization.
- Due to the flexibility of data message formats, other control structures and operating modes besides the ones commonly used with CP16/1 and CP16/2 are possible.

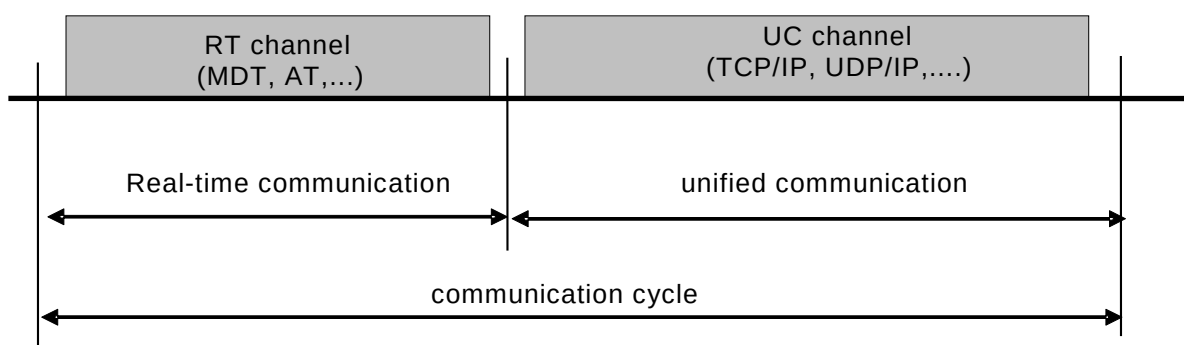


Figure 17 – General communication cycle

IEC

6.6 Communication cycles

CP16/3 (SERCOS III) synchronization differs from CP16/1 and CP16/2 as follows:

- the communication cycle times shall be selected using S-01002;
- 31,25 μ s cycle time shall be available in addition;
- only granularity 3 (250 μ s increments beyond 250 μ s cycle time) is recommended.

6.7 Drive classes

6.7.1 General

A drive class may contain parameters and functions of one or several function groups.

S-01601 shows the drive classes and versions that are implemented in a slave device (once per sub-device).

Several classes of drives are defined:

- torque axis
- velocity axis
- velocity axis with position feedback
- position axis
- positioning axis

Each drive class shall support the

- S-0-0032 Primary operation mode
- S-0-0134 Drive control
- S-0-0135 Drive status

The bit combinations of Table 32 and Table 33 are mandatory for all drive classes.