

INTERNATIONAL STANDARD

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

**Réseaux de communication industriels – Spécifications des bus de terrain –
Partie 4-16: Spécification de protocole de la couche de liaison de données –
Éléments de Type 16**



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CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
1.1 General.....	10
1.2 Specifications.....	10
1.3 Procedures.....	10
1.4 Applicability.....	10
1.5 Conformance.....	10
2 Normative references	11
3 Terms, definitions, symbols, abbreviations and conventions	11
3.1 Reference model terms and definitions.....	11
3.2 Service convention terms and definitions.....	13
3.3 Other terms and definitions	14
3.4 Abbreviations	18
3.5 Symbols	20
3.6 DLPDU IDN concept.....	21
4 DL-protocol overview.....	21
5 Basic DLPDU structure.....	22
5.1 Overview	22
5.2 MST DLPDU.....	23
5.3 MDT DLPDU	24
5.4 AT DLPDU	31
6 Network management methods.....	38
6.1 Overview	38
6.2 Enable and disable cyclic communication	38
6.3 File transfer.....	43
6.4 Status procedures	44
7 Data transmission methods	44
7.1 Overview.....	44
7.2 SVC	44
7.3 RTC	56
8 DL management	57
8.1 Overview.....	57
8.2 Access to PhL	57
9 Error handling and monitoring	62
9.1 Invalid telegrams.....	62
9.2 Response to MDT and AT telegram failure	63
9.3 Reaction to handshake timeout	64
9.4 Service channel error messages.....	65
9.5 Reaction to error messages in the service channel.....	67
9.6 Error counters in the master and the slave	67
9.7 Error effects on communication phases	69
9.8 Monitoring in the master.....	69
9.9 Monitoring in the slave	70
Annex A (normative) – IDN – Identification numbers	72
A.1 IDN specification	72

A.2 Identification numbers in numerical orders	79
A.3 Detailed specification of communication-related IDNs	80
Bibliography.....	108
Figure 1 – Relationships of DLSAPs, DLSAP-addresses and group DL-addresses	16
Figure 2 – Master service INFO field k	26
Figure 3 – Structure of the master data telegram	27
Figure 4 – Device service INFO field m	32
Figure 5 – Timing of U/D bits in CP5	36
Figure 6 – Timing of U/D bits in CP6	38
Figure 7 – Switching to CP0.....	43
Figure 8 – Phase transitions	43
Figure 9 – Service channel handling diagram.....	46
Figure 10 – Communication step proceeding diagram	48
Figure 11 – State machine for procedure command execution	53
Figure 12 – Interaction of procedure command control and acknowledgement	54
Figure 13 – Procedure command execution without interrupt	55
Figure 14 – Procedure command execution with interrupt	55
Figure 15 – Procedure command execution with error message	56
Figure 16 – Access to the transfer medium	58
Figure 17 – Timing diagram for CP0	59
Figure 18 – Telegram transmission starting times of CP1 and CP2	59
Figure 19 – Timing diagram for cyclic operation	60
Figure 20 – Telegram transmission times in CP5	61
Figure 21 – Telegram transmission times in CP6	61
Figure 22 – Required time intervals between telegrams	62
Figure A.1 – General IDN structure	73
Figure A.2 – IDN name structure.....	73
Figure A.3 – IDN data unit structure.....	76
Figure A.4 – Structure of IDN operation data with variable length	77
Figure A.5 – Example of the structure of an IDN-list.....	78
Figure A.6 – SLKN example	95
Table 1 – General telegram structure	22
Table 2 – BOF field.....	22
Table 3 – Device address field.....	23
Table 4 – FCS field	23
Table 5 – Master synchronization telegram structure	23
Table 6 – MST INFO field	24
Table 7 – Data fields of the master data telegram	24
Table 8 – Master real-time data (for each device)	25
Table 9 – Control word description (DLL)	25
Table 10 – Structure of the ID request telegram in CP1	26

Table 11 – Structure of MDT in CP5	27
Table 12 – Structure of Data Record in MDT in CP5	28
Table 13 – File block size in CP5.....	28
Table 14 – U/D control word in CP5	28
Table 15 – Structure of MDT in CP6	29
Table 16 – Structure of data record field in MDT in CP6	30
Table 17 – U/D control word in CP6	30
Table 18 – Data field of the acknowledge telegram	31
Table 19– AT real-time data (for each device).....	31
Table 20 – Status word description (DLL)	32
Table 21 – Structure of the ID acknowledge telegram in CP1	33
Table 22 – Structure of the operation data of device m in acknowledge telegram	33
Table 23 – Structure of AT in CP5	34
Table 24 – Structure of data record in AT in CP5	34
Table 25 – U/D status word in CP5	34
Table 26 – File block index in CP5.....	35
Table 27 – Structure of AT in CP6	36
Table 28 – Structure of data record in AT in CP6	36
Table 29 – File block size in CP6.....	36
Table 30 – U/D status word in CP6	37
Table 31 – File block index in CP6.....	38
Table 32 – List of IDNs element and step numbers	47
Table 33 – Condition for modifying data block elements.....	47
Table 34 – SVC channel evaluation	49
Table 35 – IDN for list transfer	50
Table 36 – Procedure command control	50
Table 37 – Procedure command acknowledgment (data status)	51
Table 38 – Allowed jitter	58
Table 39 – Jitter in t_2	60
Table 40 – Jitter in t_1	61
Table 41 – Loss or failure of master synchronization telegram (MST)	63
Table 42 – Failure of master data telegrams (MDT)	64
Table 43 – Failure of acknowledge telegrams (AT).....	64
Table 44 – Reaction to handshake timeout	64
Table 45 – Error messages	65
Table 46 – Reaction to error message	67
Table 47 – States of error counters 1 in the master for MST and AT failures	67
Table 48 – States of error counter 1 in the devices for MST-failures in CP3 and CP4	67
Table 49 – States of error counter 1 in the devices for MDT-failures in CP4.....	67
Table 50 – States of error counters 2 in the master for AT-failures.....	68
Table 51 – States of error counter 2 in the devices for MST-failures	68
Table 52 – States of error counter 2 in the devices for MDT-failures	69
Table 53 – Master monitoring.....	70

Table 54 – Slave monitoring	71
Table A.1 – Data block structure	72
Table A.2 – IDN structure	73
Table A.3 – Element 3 of IDNs	74
Table A.4 – Valid combinations of the display formats	75
Table A.5 – Data status structure	79
Table A.6 – Communication related IDN list that are relevant for Type 16	79
Table A.7 – Attributes for IDN S-0-0001	81
Table A.8 – Attributes for IDN S-0-0002	81
Table A.9 – Attributes for IDN S-0-0003	82
Table A.10 – Attributes for IDN S-0-0004	82
Table A.11 – Attributes for IDN S-0-0006	83
Table A.12 – Attributes for IDN S-0-0008	83
Table A.13 – Attributes for IDN S-0-0009	84
Table A.14 – Attributes for IDN S-0-0010	84
Table A.15 – Attributes for IDN S-0-0011	85
Table A.16 – Structure of C1D	85
Table A.17 – Attributes for IDN S-0-0014	86
Table A.18 – Structure of interface status	86
Table A.19 – Attributes for IDN S-0-0015	87
Table A.20 – Structure of telegram type parameter	88
Table A.21 – Attributes for IDN S-0-0016	88
Table A.22 – Attributes for IDN S-0-0018	89
Table A.23 – Attributes for IDN S-0-0019	89
Table A.24 – Attributes for IDN S-0-0021	90
Table A.25 – Attributes for IDN S-0-0022	90
Table A.26 – Attributes for IDN S-0-0024	91
Table A.27 – Attributes for IDN S-0-0028	91
Table A.28 – Attributes for IDN S-0-0029	92
Table A.29 – Attributes for IDN S-0-0087	92
Table A.30 – Attributes for IDN S-0-0088	93
Table A.31 – Attributes for IDN S-0-0089	93
Table A.32 – Attributes for IDN S-0-0090	94
Table A.33 – Attributes for IDN S-0-0096	94
Table A.34 – Structure of SLKN	95
Table A.35 – Attributes for IDN S-0-0097	95
Table A.36 – Structure of Mask C2D	96
Table A.37 – Attributes for IDN S-0-0098	96
Table A.38 – Structure of Mask C3D	96
Table A.39 – Attributes for IDN S-0-0127	97
Table A.40 – Attributes for IDN S-0-0128	97
Table A.41 – Attributes for IDN S-0-0134	98
Table A.42 – Attributes for IDN S-0-0135	98

Table A.43 – Attributes for IDN S-0-0143	99
Table A.44 – Structure of Type 16 version	99
Table A.45 – Attributes for IDN S-0-0185	100
Table A.46 – Attributes for IDN S-0-0186	100
Table A.47 – Attributes for IDN S-0-0187	101
Table A.48 – Attributes for IDN S-0-0188	101
Table A.49 – Attributes for IDN S-0-0301	102
Table A.50 – Attributes for IDN S-0-0303	102
Table A.51 – Attributes for IDN S-0-0305	103
Table A.52 – Attributes for IDN S-0-0307	103
Table A.53 – Attributes for IDN S-0-0394	104
Table A.54 – Attributes for IDN S-0-0395	104
Table A.55 – Attributes for IDN S-0-0396	105
Table A.56 – Attributes for IDN S-0-0397	105
Table A.57 – Attributes for IDN S-0-0413	106
Table A.58 – Attributes for IDN S-0-0414	106
Table A.59 – Attributes for IDN S-0-0415	107
Table A.60 – Attributes for IDN S-0-0416	107

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**INDUSTRIAL COMMUNICATION NETWORKS –
FIELDBUS SPECIFICATIONS –****Part 4-16: Data-link layer protocol specification – Type 16 elements**

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International Standard IEC 61158-4-16 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This first edition and its companion parts of the IEC 61158-4 subseries cancel and replace IEC 61158-4:2003. This edition of this part constitutes a technical addition. This publication, together with its companion parts for Type 16, also partially replaces IEC 61491:2002 which is at present being revised. IEC 61491 will be issued as a technical report.

This edition of IEC 61158-4 includes the following significant changes from the previous edition:

- a) deletion of the former Type 6 fieldbus, and the placeholder for a Type 5 fieldbus data link layer, for lack of market relevance;

- b) addition of new types of fieldbuses;
- c) division of this part into multiple parts numbered -4-1, -4-2, ..., -4-19.

This bilingual version (2013-09) corresponds to the monolingual English version, published in 2007-12.

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

FDIS	Report on voting
65C/474/FDIS	65C/485/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.

The French version of this standard has not been voted upon.

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

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

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

NOTE The revision of this standard will be synchronized with the other parts of the IEC 61158 series.

The list of all the parts of the IEC 61158 series, under the general title *Industrial communication networks – Fieldbus specifications*, can be found on the IEC web site.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This part of IEC 61158 is one of a series produced to facilitate the interconnection of automation system components. It is related to other standards in the set as defined by the “three-layer” fieldbus reference model described in IEC/TR 61158-1.

The data-link protocol provides the data-link service by making use of the services available from the physical layer. The primary aim of this standard is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer data-link entities (DLEs) at the time of communication. These rules for communication are intended to provide a sound basis for development in order to serve a variety of purposes:

- a) as a guide for implementors and designers;
- b) for use in the testing and procurement of equipment;
- c) as part of an agreement for the admittance of systems into the open systems environment;
- d) as a refinement to the understanding of time-critical communications within OSI.

This standard is concerned, in particular, with the communication and interworking of sensors, effectors and other automation devices. By using this standard together with other standards positioned within the OSI or fieldbus reference models, otherwise incompatible systems may work together in any combination.

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-16: Data-link layer protocol specification – Type 16 elements

1 Scope

1.1 General

The data-link layer provides basic time-critical messaging communications between devices in an automation environment.

This protocol provides communication opportunities to all participating data-link entities

- a) in a synchronously-starting cyclic manner, according to a pre-established schedule, and
- b) in a cyclic or acyclic asynchronous manner, as requested each cycle by each of those data-link entities.

Thus this protocol can be characterized as one which provides cyclic and acyclic access asynchronously but with a synchronous restart of each cycle.

1.2 Specifications

This standard specifies

- a) procedures for the timely transfer of data and control information from one data-link user entity to a peer user entity, and among the data-link entities forming the distributed data-link service provider;
- b) the structure of the fieldbus DLPDUs used for the transfer of data and control information by the protocol of this standard, and their representation as physical interface data units.

1.3 Procedures

The procedures are defined in terms of

- a) the interactions between peer DL-entities (DLEs) through the exchange of fieldbus DLPDUs;
- b) the interactions between a DL-service (DLS) provider and a DLS-user in the same system through the exchange of DLS primitives;
- c) the interactions between a DLS-provider and a Ph-service provider in the same system through the exchange of Ph-service primitives.

1.4 Applicability

These procedures are applicable to instances of communication between systems which support time-critical communications services within the data-link layer of the OSI or fieldbus reference models, and which require the ability to interconnect in an open systems interconnection environment.

Profiles provide a simple multi-attribute means of summarizing an implementation's capabilities, and thus its applicability to various time-critical communications needs.

1.5 Conformance

This standard also specifies conformance requirements for systems implementing these procedures. This part of this standard does not contain tests to demonstrate compliance with such requirements.

2 Normative references

The following referenced documents are indispensable for the application of this standard. 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 (Ed.4.0), *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 61158-3-16, *Industrial communication networks – Fieldbus specifications - Part 3-16: Data-link layer service definition – Type 16 elements*

IEC 61800-7-20x (all subparts), *Adjustable speed electrical power drive systems – Part 7-20x: Generic interface and use of profiles for power drive systems – Profile type x specification*¹

ISO/IEC 7498-1, *Information technology – Open Systems Interconnection – Part 1: Basic Reference Model: The Basic Model*

ISO/IEC 7498-3, *Information technology – Open Systems Interconnection – Part 3: Basic Reference Model: Naming and addressing*

ISO/IEC 10731, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*

ISO/IEC 13239, *Information technology – Telecommunications and information exchange between systems – High-level data link control (HDLC) procedures*

ITU X.25, *Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit*

3 Terms, definitions, symbols, abbreviations and conventions

For the purposes of this document, the following terms, definitions, symbols, abbreviations and conventions apply.

3.1 Reference model terms and definitions

This standard is based in part on the concepts developed in ISO/IEC 7498-1 and ISO/IEC 7498-3, and makes use of the following terms defined therein:

3.1.1 DL-address	[7498-3]
3.1.2 DL-address-mapping	[7498-1]
3.1.3 called-DL-address	[7498-3]
3.1.4 calling-DL-address	[7498-3]
3.1.5 centralized multi-end-point-connection	[7498-1]
3.1.6 DL-connection	[7498-1]
3.1.7 DL-connection-end-point	[7498-1]

¹ At present, these subparts are IEC 61800-7-201, 7-202, 7-203 and 7-204.

3.1.8 DL-connection-end-point-identifier	[7498-1]
3.1.9 DL-connection-mode transmission	[7498-1]
3.1.10 DL-connectionless-mode transmission	[7498-1]
3.1.11 correspondent (N)-entities	[7498-1]
correspondent DL-entities (N=2)	
correspondent Ph-entities (N=1)	
3.1.12 DL-duplex-transmission	[7498-1]
3.1.13 (N)-entity	[7498-1]
DL-entity (N=2)	
Ph-entity (N=1)	
3.1.14 DL-facility	[7498-1]
3.1.15 flow control	[7498-1]
3.1.16 (N)-layer	[7498-1]
DL-layer (N=2)	
Ph-layer (N=1)	
3.1.17 layer-management	[7498-1]
3.1.18 DL-local-view	[7498-3]
3.1.19 DL-name	[7498-3]
3.1.20 naming-(addressing)-domain	[7498-3]
3.1.21 peer-entities	[7498-1]
3.1.22 primitive name	[7498-3]
3.1.23 DL-protocol	[7498-1]
3.1.24 DL-protocol-connection-identifier	[7498-1]
3.1.25 DL-protocol-data-unit	[7498-1]
3.1.26 DL-relay	[7498-1]
3.1.27 reset	[7498-1]
3.1.28 responding-DL-address	[7498-3]
3.1.29 routing	[7498-1]
3.1.30 segmenting	[7498-1]
3.1.31 (N)-service	[7498-1]
DL-service (N=2)	
Ph-service (N=1)	
3.1.32 (N)-service-access-point	[7498-1]
DL-service-access-point (N=2)	
Ph-service-access-point (N=1)	
3.1.33 DL-service-access-point-address	[7498-3]
3.1.34 DL-service-connection-identifier	[7498-1]

3.1.35 DL-service-data-unit	[7498-1]
3.1.36 DL-simplex-transmission	[7498-1]
3.1.37 DL-subsystem	[7498-1]
3.1.38 systems-management	[7498-1]
3.1.39 DL-user-data	[7498-1]

3.2 Service convention terms and definitions

This standard also makes use of the following terms defined in ISO/IEC 10731 as they apply to the data-link layer:

3.2.1 acceptor
3.2.2 asymmetrical service
3.2.3 confirm (primitive); requestor.deliver (primitive)
3.2.4 deliver (primitive)
3.2.5 DL-confirmed-facility
3.2.6 DL-facility
3.2.7 DL-local-view
3.2.8 DL-mandatory-facility
3.2.9 DL-non-confirmed-facility
3.2.10 DL-provider-initiated-facility
3.2.11 DL-provider-optional-facility
3.2.12 DL-service-primitive; primitive
3.2.13 DL-service-provider
3.2.14 DL-service-user
3.2.15 DL-user-optional-facility
3.2.16 indication (primitive); acceptor.deliver (primitive)
3.2.17 multi-peer
3.2.18 request (primitive); requestor.submit (primitive)
3.2.19 requestor
3.2.20 response (primitive); acceptor.submit (primitive)
3.2.21 submit (primitive)
3.2.22 symmetrical service

3.3 Other terms and definitions

3.3.1

acknowledge telegram (AT)

telegram, in which each slave inserts its data

3.3.2

broadcast

transmission to all devices in a network without any acknowledgment by the receivers

3.3.3

communication cycle

fixed time period between two master synchronization telegrams in which real-time telegrams are transmitted in the RT channel and non real-time telegrams are transmitted in the IP channel

3.3.4

control unit

control device (e.g., a PLC as specified in the IEC 61131 standard family)

3.3.5

control word

two adjacent octets inside the master data telegram containing commands for the addressed device

3.3.6

cycle time

duration of a communication cycle

3.3.7

cyclic communication

periodic exchange of telegrams

3.3.8

cyclic data

part of a telegram, which does not change its meaning during cyclic operation of the network

3.3.9

cyclic operation

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

3.3.10

data exchange

demand dependent, non cyclic transmission (service channel), whereas transmission of information occurs upon master request

3.3.11

delimiter, telegram delimiter

beginning and ending identifiers of a telegram (eight bits: 01111110_B)

3.3.12

device

a slave in the communication network, (e.g., a power drive system as defined in the IEC 61800 standard family, I/O stations as defined in the IEC 61131 standard family)

3.3.13**device address field**

address field (eight bits) containing the address of the device

3.3.14**device status**

four adjacent octets inside the acknowledge telegram containing status information for each device

3.3.15**DLE station identifier**

network address assigned to a DLE

3.3.16**DLE station slot**

unit (granularity of one) of position dependent mapping (for cyclic data field) of which a DLE may occupy one or more, delineated by the range beginning at the DLE station identifier with a length equal to the configured number of occupied slots

3.3.17**DL-segment, link, local link**

single DL-subnetwork in which any of the connected DLEs may communicate directly, without any intervening DL-relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the period(s) of attempted communication

3.3.18**DLSAP**

distinctive point at which DL-services are provided by a single DL-entity to a single higher-layer entity

NOTE This definition, derived from ISO/IEC 7498-1, is repeated here to facilitate understanding of the critical distinction between DLSAPs and their DL-addresses.

3.3.19**DL(SAP)-address**

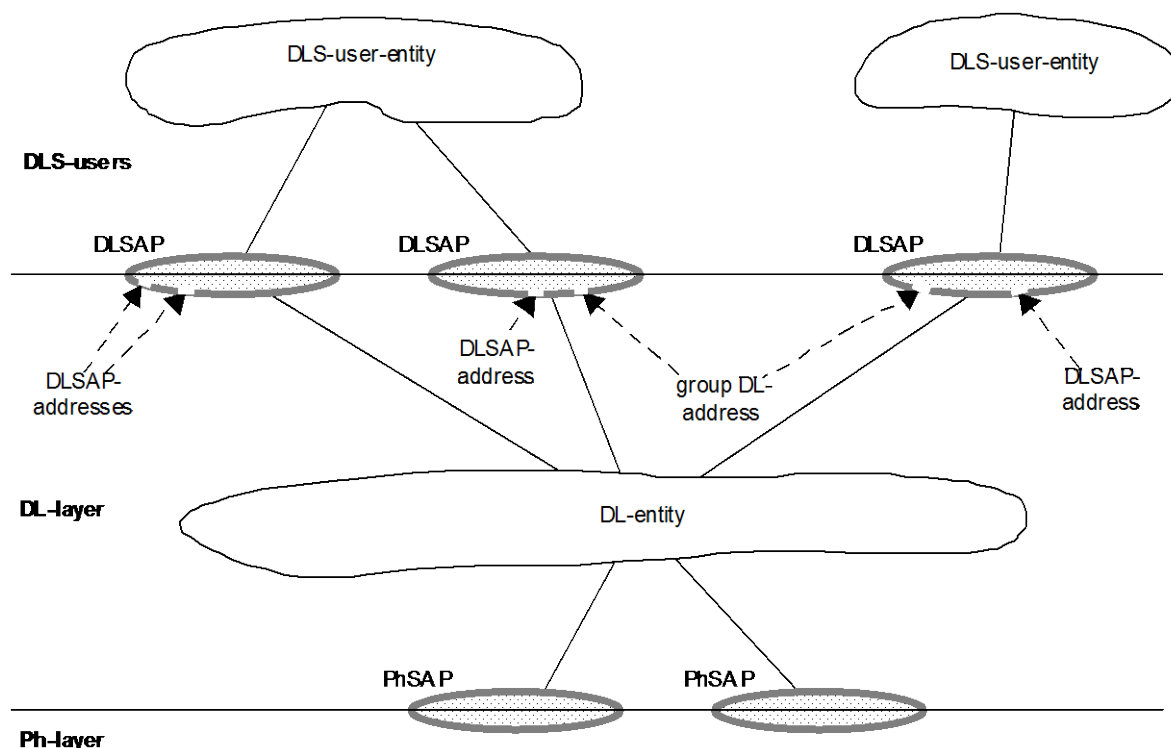
either an individual DLSAP-address, designating a single DLSAP of a single DLS-user, or a group DL-address potentially designating multiple DLSAPs, each of a single DLS-user

NOTE This terminology is chosen because ISO/IEC 7498-3 does not permit the use of the term DLSAP-address to designate more than a single DLSAP at a single DLS-user.

3.3.20**(individual) DLSAP-address**

DL-address that designates only one DLSAP within the extended link

NOTE A single DL-entity may have multiple DLSAP-addresses associated with a single DLSAP. (See Figure 1.)



NOTE 1 DLSAPs and PhSAPs are depicted as ovals spanning the boundary between two adjacent layers.

NOTE 2 DL-addresses are depicted as designating small gaps (points of access) in the DLL portion of a DLSAP.

NOTE 3 A single DL-entity may have multiple DLSAP-addresses and group DL-addresses associated with a single DLSAP.

Figure 1 – Relationships of DLSAPs, DLSAP-addresses and group DL-addresses

3.3.21 element

part of IDNs – each IDN has 7 elements, whereas each one has a specific meaning (e.g., number, name, data)

3.3.22 extended link

DL-subnetwork, consisting of the maximal set of links interconnected by DL-relays, sharing a single DL-name (DL-address) space, in which any of the connected DL-entities may communicate, one with another, either directly or with the assistance of one or more of those intervening DL-relay entities

NOTE An extended link may be composed of just a single link.

3.3.23 frame

denigrated synonym for DLPDU

3.3.24 frame check sequence (FCS)

check character sequence consists of a given number of bits (e.g., 16, 32) which is generated by means of a cyclic redundancy check (CRC) character polynomial in accordance with ITU-T X.25

3.3.25**group DL-address**

DL-address that potentially designates more than one DLSAP within the extended link. A single DL-entity may have multiple group DL-addresses associated with a single DLSAP. A single DL-entity also may have a single group DL-address associated with more than one DLSAP

3.3.26**hot plug**

possibility to open the communication network and insert or remove slaves while the network is still in real-time operation

3.3.27**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

3.3.28**master**

node, which assigns the other nodes (i.e., slaves) the right to transmit

3.3.29**master data telegram (MDT)**

telegram, in which the master inserts its data

3.3.30**master DLE**

DLE that performs the functions of network master

3.3.31**master synchronization telegram (MST)**

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

3.3.32**node**

single DL-entity as it appears on one local link

3.3.33**PDS enable**

command to close the feedback loop(s) of a power drive system

3.3.34**PDS on**

command that the power stage of a power drive system can be activated

3.3.35**physical layer**

first layer of the ISO-OSI reference model

3.3.36**protocol**

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

3.3.37**real-time data**

part of the telegram that does not change its meaning during cyclic operation of the interface

3.3.38

receiving DLS-user

DL-service user that acts as a recipient of DL-user-data

NOTE A DL-service user can be concurrently both a sending and receiving DLS-user.

3.3.39

S-0-nnnn

designation of IDNs

3.3.40

sending DLS-user

DL-service user that acts as a source of DL-user-data

3.3.41

service channel (SVC)

non real-time transmission of information upon master request during RT channel

3.3.42

status word

two adjacent octets inside the acknowledge telegram containing status information of a device

3.3.43

slave

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

3.3.44

slave DLE

DLE that performs the functions of network slave

3.3.45

station

node

3.3.46

telegram

DLPDU

3.3.47

topology

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

3.4 Abbreviations

3.4.1 AHS service transport handshake of the device (acknowledge HS)

3.4.2 ASCII American Standard Code for Information Interchange

3.4.3 AT acknowledge telegram

3.4.4 BOF begin of frame

3.4.5 C1D class 1 diagnostic

3.4.6 C2D class 2 diagnostic

3.4.7 C3D class 3 diagnostic

3.4.8 CA procedure command acknowledgment

3.4.9 CC	cross communication between participants
3.4.10 CP	communication phase
3.4.11 CPS	communication phase switching
3.4.12 CRC	cyclic redundancy check
3.4.13 DL-	Data-link layer (as a prefix)
3.4.14 DLC	DL-connection
3.4.15 DLCEP	DL-connection-end-point
3.4.16 DLE	DL-entity (the local active instance of the data-link layer)
3.4.17 DLL	DL-layer
3.4.18 DLPCI	DL-protocol-control-information
3.4.19 DLPDU	DL-protocol-data-unit
3.4.20 DLM	DL-management
3.4.21 DLME	DL-management Entity (the local active instance of DL-management)
3.4.22 DLMS	DL-management Service
3.4.23 DLS	DL-service
3.4.24 DLSAP	DL-service-access-point
3.4.25 DLSDU	DL-service-data-unit
3.4.26 EOF	end of frame
3.4.27 FCS	frame check sequence
3.4.28 FIFO	First-in first-out (queuing method)
3.4.29 HS	service channel handshake (see AHS and MHS)
3.4.30 IDN	Identification Number
3.4.31 LSB	least significant bit
3.4.32 Mbit/s	megabit per second
3.4.33 MDT	master data telegram
3.4.34 MDT MST	type 19 header in MDT
3.4.35 MHS	service transport handshake of the master
3.4.36 MST	master synchronization telegram
3.4.37 OSI	Open systems interconnection
3.4.38 PDS	power drive system (see IEC 61800 standard family)
3.4.39 Ph-	Physical layer (as a prefix)
3.4.40 PhE	Ph-entity (the local active instance of the physical layer)
3.4.41 PhL	Ph-layer

3.4.42 QoS	Quality of service
3.4.43 RE	Resource element
3.4.44 RTC	Real-time channel
3.4.45 SERCOS	serial real-time communication system interface
3.4.46 SI	Sub Index
3.4.47 SVC	Service channel

3.5 Symbols

3.5.1 ADR	device address ($1 \leq \text{ADR} \leq 254$) adjusted directly on the device e.g., using a selector switch
3.5.2 INFO	service channel information
3.5.3 J_{t_2}	jitter in t_2
3.5.4 $J_{t_{\text{scyc}}}$	jitter in t_{Scyc}
3.5.5 MDT0	master data telegram with synchronization data that the slaves evaluates
3.5.6 n_{min}	shut-off velocity in the PDS after C1D error
3.5.7 SLKN	slave identification parameter, slave arrangement
3.5.8 SVC	service channel
3.5.9 t_1	AT transmission starting time
3.5.10 $t_{1,m}$	AT transmission starting time with data record m of slave XX
3.5.11 $t_{1\text{min}}$	shortest AT transmission starting time
3.5.12 $t_{1\text{min},m}$	shortest AT transmission starting time with data record m of slave XX after receiving the MST
3.5.13 t_2	MDT transmission starting time
3.5.14 t_3	command value valid time
3.5.15 t_5	minimum feedback processing time
3.5.16 t_{ATAT}	transmit to transmit recovery time in a slave with several slaves
3.5.17 t_{ATMT}	transmit/receive transmission time
3.5.18 $t_{\text{ATMT},M}$	transmit/receive transmission time which slave M needs between transmitting its AT and being prepared for receiving an MDT
3.5.19 t_{ATRP}	maximum transition time in a slave to switch from transmitting an AT to repeater function
3.5.20 t_{MTSG}	command value processing time
3.5.21 t_{MTSY}	receive to receive recovery time in a slave

- 3.5.22** $t_{\text{MTSY.K}}$ recovery time of the last slave after the reception of an MDT to switch over for receiving the next MST (the last slave is the one which is served with data record K)
- 3.5.23** t_{Ncyc} control unit cycle time
- 3.5.24** t_{RPAT} maximum transition time in a slave to switch from the repeater function to the transmitter function for the AT
- 3.5.25** t_{Scyc} communication cycle time
- 3.5.26** **XX** address of a device

3.6 DL PDU IDN concept

All data classes that are handled by Type 16 networks have been assigned identification numbers (IDNs). They include real-time data (commands and feedback values), parameters, and procedures. Several IDNs relate to the application and are defined in their relevant standards (e.g., IEC 61800-7-20x for Power Drive Systems).

Refer to Annex A for additional information.

4 DL-protocol overview

Type 16 profile provides a highly optimized means of interchanging fixed-length real-time data and variable-length segmented messages between a single master device and a set of slave devices, interconnected in a ring topology. The exchange of real-time data is totally synchronous by configuration and is unaffected by the messaging traffic.

The device addresses are set by the user, for example, using a selector. Additional devices may be added whenever required, even during operation, without affecting the address selections, which already exist. The determination of the number, identity and characteristics of each device may be configured or may be detected automatically at start-up.

Slave interfaces shall be used to connect the devices to the network. At the physical layer, a slave represents the connection of one or more devices to the network. Logically, one slave with several devices shall act the same as several slaves with one device each.

There are two classes of Type 16 DLE:

- a) master DLE;
- b) slave DLE.

Only the master DLE is able to initiate the cyclic transmission.

All Type 16 data exchange between the master and the slaves shall take place using defined telegrams. There shall be three sub types of telegrams.

- Master synchronization telegram (MST). MSTs shall be broadcasted by the master at the beginning of a transmission cycle for synchronizing all slaves. They do not transmit any data.
- Master data telegram (MDT). MDTs shall be broadcasted by the master once during each cycle for transmitting its data to all slaves (e.g. command values).
- Device telegrams (AT). ATs shall be sent by each slave once during each cycle for transmitting its data to the master (e.g. feedback values).

Type 16 networks shall not be used for transmitting any other telegrams.

Each device data record in the MDT or AT shall contain a fixed and a configurable part. The fixed part of the data record shall always be present, while the structure of the configurable part of the data record shall be determined for every device by initialization parameters, according to its operation mode and the desired data volume.

5 Basic DLPDU structure

5.1 Overview

5.1.1 General Type 16 telegram structure

Type 16 networks use specific DLPDUs for transporting Type 16 data.

The structure of the DLPDU depends on the telegram type (MST, MDT and AT) and the specific communication phase (CP0-CP6).

The general structure of Type 16 telegrams is shown in Table 1.

Table 1 – General telegram structure

Frame part	Data field	Data type	Value/description
Type 16 telegrams	BOF	OCTET[1]	Telegram delimiter
	ADR	OCTET[1]	Address field
	Data field	OCTET[j × x]	Configurable length
	FCS	OCTET[2]	Frame check sequence
	EOF	OCTET[1]	Telegram delimiter

The administrative segment of the telegram (BOF, ADR, FCS, and (EOF) is required for the transmission of any telegram. The master shall either address telegrams to a specific target or use a broadcast address to transmit messages to all devices concurrently. Slave telegrams (ATs) shall contain the source address.

The User application data shall contain specific information and be handled differently according to the three telegram types and the status of the interface.

5.1.2 BOF telegram delimiter (beginning of frame)

The BOF delimiter shall indicate the start of the telegram. Table 2 shows the content of the field.

Table 2 – BOF field

Bit no,	Value	Description
7	0	Fix value
6-1	1	Fix value
0	0	Fix value

5.1.3 ADR address field

The address field shall be as specified in Table 3.

Table 3 – Device address field

Bit no,	Value	Description
7-0		Device address
	0	Logical device removal
	1 - 254	Device addresses for operation
	255	Reserved

The device address ADR shall be in the range $0 \leq \text{ADR} \leq 255$. It shall be set by the user on the device, for example, using a selector. Each device shall then have its own address ADR. The addresses of all devices that are connected to the same slave shall be in a row.

Any device address in the range $1 \leq \text{ADR} \leq 254$ shall be allocated to not more than one device.

The device address ADR = 0 may be allocated to any number of devices. Devices with such an address shall not generate any telegrams except during network initialization. This makes it possible to remove devices logically from the communication (e.g., for testing purposes).

The device address ADR = 255 shall be reserved.

5.1.4 FCS frame check sequence

A cyclic redundancy check (CRC) shall be used by the transmit and receive algorithms to generate a CRC value for the FCS field. The frame check sequence (FCS) field shall contain a 2 octet (16-bit) cyclic redundancy check (CRC) value. This value shall be computed as a function of the contents of the address and data fields. The FCS shall be generated by the transmitter. The encoding shall be defined as specified in ISO/IEC 13239.

Table 4 – FCS field

Bit no,	Value	Description
15-0		Calculated CRC

5.1.5 EOF telegram delimiter (end of frame)

The EOF delimiter shall indicate the end of a Type 16 telegram. Its content is the same as the BOF telegram delimiter (see Table 2).

5.1.6 Data field

The data field shall be structured according to the three telegram types and the status of the interface (initialization). All transmitted data is allowed to have arbitrary bit sequences of length $j \times 8$ bits.

5.2 MST DLPDU

In the MST, the data field shall only indicate the operation status of the interface and shall be structured as shown in Table 5.

Table 5 – Master synchronization telegram structure

Frame part	Data field	Data type	Value/description
Master data field	INFO	OCTET[1]	Operation status

The INFO field in a MST shall indicate the operation status of the interface. Table 6 shows the content of the field.

Table 6 – MST INFO field

Bit no,	Value	Meaning
7-3	0	Fix value
2-0		Operation status of the interface
	000 _B	CP0 (master attempts to close the ring)
	001 _B	CP1 (address and device identification)
	010 _B	CP2 (parameter mode)
	011 _B	CP3 (cyclic parameter mode)
	100 _B	Reserved
	101 _B	CP4 (cyclic operation)
	010 _B	CP5 (file download)
	111 _B	CP6 (file upload)

5.3 MDT DLPDU

5.3.1 Introduction

5.3.1.1 General MDT telegram structure

Except during initialization, the MDT shall be handled as a broadcast telegram to save time. The data field of the MDT shall be divided into as many data records as there are slaves serviced by the master (see Table 7). The MDT shall contain all the data records which are cyclically sent to all connected slaves by the master.

Table 7 – Data fields of the master data telegram

Frame part	Data field	Data type	Value/description
MDT real-time data field	Real-time data slave #1	OCTET[see Table 8]	
	Real-time data slave #2	OCTET[see Table 8]	
	...		(And so on for slaves #3 to #(K-1).)
	Real-time data slave #K	OCTET[see Table 8]	

Individual data records may have different lengths. During initialization, every data record shall be assigned to its respective device depending upon its address ADR.

They shall remain constant during normal operation, and can be modified only by reinitializing the system, if the configuration requires it.

Each device shall have its own real-time data field as specified in Table 8.

Table 8 – Master real-time data (for each device)

Frame part	Data Field	Data Type	Value/Description
Real-time data slave #k	Control	OCTET[2]	
	Master service INFO	OCTET[see 5.3.1.3]	
	Configurable real-time data	OCTET[see 5.3.4]	

5.3.1.2 Control k – control word for device XX

Table 9 describes the control word as it shall be.

Table 9 – Control word description (DLL)

Bit no,	Value	Control word description
15-11		Reserved for application profile (e.g. IEC 61800-7-20x)
10		Reserved for application layer (IEC 61158-6-16)
9-8		Reserved for application profile (e.g. IEC 61800-7-20x)
7-6		Reserved for application layer (IEC 61158-6-16)
5-3		Data block element
	000	Service channel not active, close service channel or break a transmission in progress
	001	IDN of the operation data. The service channel is closed for the previous IDN and opened for a new IDN
	010	Name of operation data
	011	Attribute of operation data
	100	Unit of the operation data
	101	Minimum input value
	110	Maximum input value
	111	Operation data
2		Bit last transmission
	0	Transmission in progress
	1	Last transmission
1		R/W (read/write)
	0	Read service INFO
	1	Write service INFO
0		MHS (master handshake bit)
	toggle	Service transport handshake of the master

5.3.1.3 Master service INFO k

The length of this field shall be adjusted by the telegram type (S-0-0015) for CP3 and CP4. It shall be 2, 4, 6 or 8 octets long in CP3 and CP4, programmable by telegram type (S-0-0015). It shall always be 2 octets long in CP1 and CP2.

The master service INFO field shall be the container for the non-cyclic data exchange from master to device XX which takes place in steps in special data fields of the telegram.

Figure 2 describes the master service info field as it shall be.

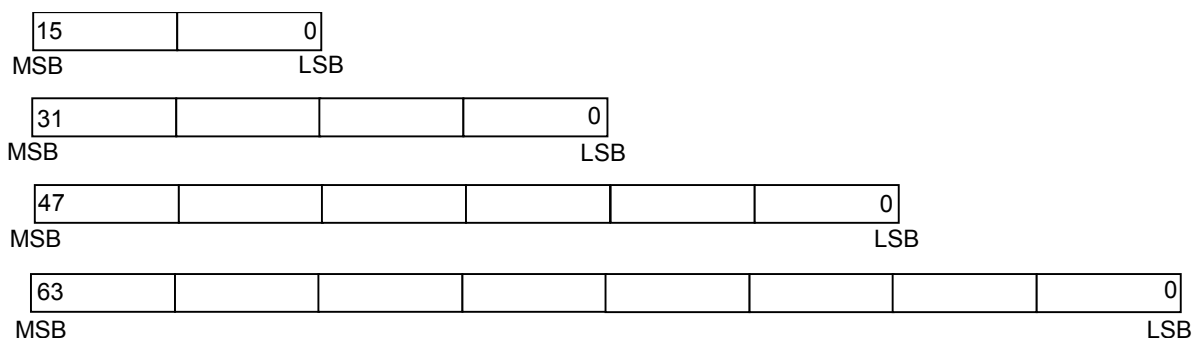


Figure 2 – Master service INFO field k

5.3.2 CP1 and CP2

Device specific identification MDTs (ID request telegrams) shall be used to request the device addresses. Their structure is shown in Table 10.

Table 10 – Structure of the ID request telegram in CP1

Frame part	Data field	Data type	Value/description
Master data field = ID request telegram in CP1	Control	OCTET[2]	0x0001
	Master service INFO	OCTET[2]	

The addressed device shall respond by sending the identification AT (ID acknowledge telegram).

Telegrams in CP2 shall have the same structure as in CP1, but the contents of master service INFO shall now be valid.

5.3.3 CP3

The configurable real-time data field of the MDT shall be used for transmitting individual real-time data to any device. Only element 7 of the data block, configured with a length of two, four or eight octets shall be used. The telegram type parameter S-0-0015 shall determine which operation data is included in the configurable real-time data field of the MDT. The appropriate operation data for standard telegrams shall be defined by this parameter. The structure of the application telegram shall be determined by the configuration list labeled S-0-0024.

The MDT shall be structured as shown in Figure 3. The data field of the MDT shall have as many data records as there are devices which are serviced by the master. Individual data records may vary in length. The assignment of a data record to a device with address XX shall take place during initialization via IDN S-0-0009.

Only the fixed part of the data records shall be used. The configurable part of the data records does not care, but it shall have the number of octets required for cyclical operation. The positions of the fixed part of the data records relevant to the individual devices shall have been transmitted during CP2 with the corresponding communication parameters.

In the control word of the MDT, bit 10 (control unit synchronization bit) shall be valid from CP3 on. This bit shall be set to 0 during phases 0 to 2. In CP3, the control unit shall start the interpolation cycle and keep it steady. Bit 10 of the control word in the MDT shall be inverted with each interpolation cycle.

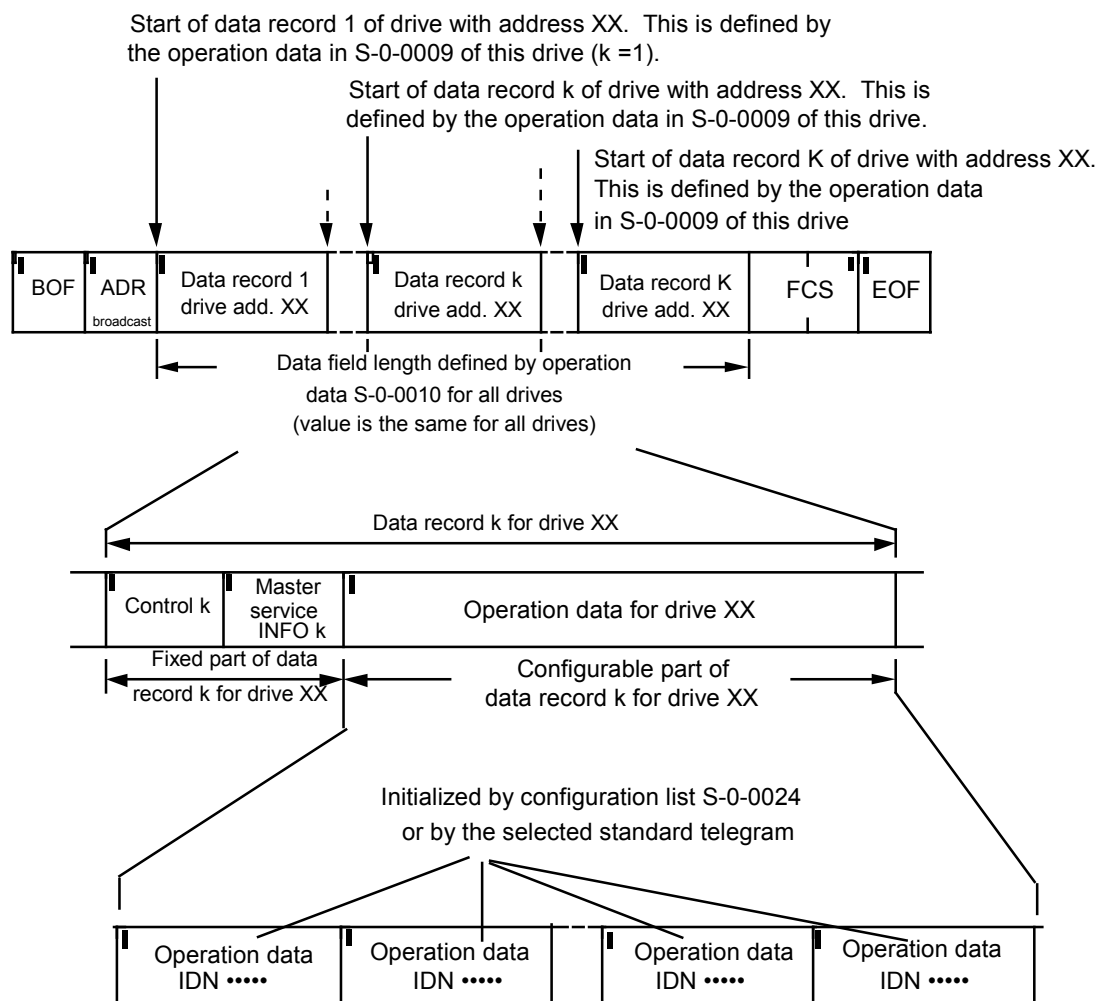


Figure 3 – Structure of the master data telegram

5.3.4 CP4

The MDT shall be structured as shown in Figure 3. The configurable parts of the data records shall be filled with command values which shall have been determined by the parameters transmitted during CP2. The positions of the fixed part of the data records relevant to the individual devices shall have been transmitted during CP2 with the corresponding communication parameters.

5.3.5 CP5

5.3.5.1 CP5 master data description

Table 11 shows the form of the Master Data Telegram for CP5.

Table 11 – Structure of MDT in CP5

Frame part	Data field	Data type	Value/description
Master data field MDT in CP5	Control	OCTET[2]	Unused
	Master service INFO	OCTET[2]	Unused
	Data Record	OCTET[see Table 12]	

The Control Word and the Master Service INFO shall be unused in CP5. The Data Record for the CP5 MDT shall be as specified in Table 12. The File Block size shall be set by the transmission rate as shown in Table 13.

Table 12 – Structure of Data Record in MDT in CP5

Frame part	Data field	Data type	Value/description
Data Record	U/D Control	OCTET[4]	
	File Block Index	OCTET[4]	
	File Block	OCTET[see Table 13]	

Table 13 – File block size in CP5

Transmission rate (Mbit/s)	File block size (octets)	MDT length (octets)	AT length (octets)
2	128	140	12
4	256	268	12
8	512	524	12
16	1024	1036	12

5.3.5.2 U/D control word in CP5

Table 14 defines the bits for the U/D Control Word in the CP5 MDT.

Table 14 – U/D control word in CP5

Bit 31	Value	Meaning
	0	Type 16 interface defined file types
	1	User defined file types
30 - 16		File type identification number
15 - 3		(Reserved)
2		Enable
	0	No file block transfer requested U/D Control word = 0x0001 U/D Status word = 0x0001
	1	File block transfer requested
1		Final Block
	0	Not last block of file transfer
	1	Final block of file transfer
0		U/D Handshake
	toggle	U/D Handshake of master

Before a file transfer may begin, the enable bit, bit 2 in the U/D Control word, shall be set low and the U/D Handshake bit, bit 0 in the U/D Control word shall be set high. If the slave handshake bit matches the master handshake bit, file transfers may begin. File transfers shall be initiated as follows:

- Step 1: Set the File Block Index to 0x0000.
- Step 2: Set the data to be transferred to the MDT File Block Data field.

- Step 3: Set the file type identification number to the File Type Qualifier and File Type Identification Number bits to the file type to be sent.
- Step 4: Set the Enable bit true.
- Step 5: Toggle U/D Handshake bit.

The master shall not change the MDT until the slave has toggled the U/D Handshake bit in the AT to match that of the MDT. If the slave has not toggled the U/D Handshake bit within 10 communication cycles, a fault in the slave shall be assumed.

When the slave toggles the U/D Handshake bit to match that of the master, the slave may also set the U/D Busy bit in the AT indicating that it is processing the data file block being transferred. Only the U/D Handshake bit in the U/D Status word shall be valid while the U/D Busy bit is set. When the slave has completed transfer of the data block and verified the file type and block number, it shall return the File Type Qualifier, File Type Identification Number, set error bits as appropriate and clear the U/D Busy bit in the AT. The master shall not initiate a new data transfer to the same slave until the U/D Handshake bit in that slave AT matches that of the master and the U/D Busy bit is 0.

Subsequent data blocs may be sent by incrementing the file block index of step 1 above and repeating steps 2 through 5. In the event the slave returns an error condition on receipt of any file block, the master may repeat the same file block by leaving the File Block Index unchanged.

The Final Block bit shall be set true when transferring the last block in a series of data transfers. This bit may be used in the slave to complete the file transfer process. This process is not part of this specification.

5.3.5.3 File block index and file block in CP5 (MDT)

A file can be divided into File Blocs that can be downloaded to a slave one File Block at a time. The contents of a file, use and placement of the file by the slave are dependent upon manufacturer implementation. The File Block Index shall be used to indicate which File Block is being transmitted. File blocs shall normally be sent sequentially beginning with File Block 0 and incrementing the block number until the entire file has been sent.

5.3.6 CP6

5.3.6.1 Introduction

Table 15 shows the form of the Master Data Telegram for CP6.

Table 15 – Structure of MDT in CP6

Frame part	Data field	Data type	Value/description
Master data field MDT in CP6	Control	OCTET[2]	Unused
	Master service INFO	OCTET[2]	Unused
	Data Record	OCTET[see Table 16]	

The Control Word and the Master Service INFO shall be unused in CP6. The Data Record for the CP6 MDT shall be as specifies in Table 16.

Table 16 – Structure of data record field in MDT in CP6

Frame part	Data field	Data type	Value/description
Data Record	U/D Control	OCTET[4]	
	File Block Index	OCTET[4]	

5.3.6.2 U/D control word in CP6

Table 17 defines the bits for the U/D Control word in the CP6 MDT.

Table 17 – U/D control word in CP6

Bits	Value	Meaning
31		File type qualifier
	0	Type 16 specific file types
	1	User defined file types
30 - 16		File type identification number
15 - 3		(Reserved)
2		Enable
	0	No file block transfer requested U/D Control word = 0x0001 U/D Status word = 0x0001
	1	File block transfer requested
1		(Reserved)
0		U/D Handshake
	toggle	U/D Handshake of master

Before a file transfer can begin, the enable bit, bit 2 in the U/D Control word, shall be set low and the U/D Handshake bit, bit 0 in the U/D Control word shall be set high. If the slave handshake bit matches the master handshake bit, file transfers shall begin. File transfers shall be initiated following these steps:

- Step 1: Set the File Block Index to 0x0000.
- Step 2: Set the file type number to the File Type Qualifier and File Type Identification Number bits to the file type to be sent.
- Step 3: Set the Enable bit true.
- Step 4: Toggle the U/D Handshake bit.

The slave shall respond by setting the U/D Busy bit true and toggling the U/D Handshake bit in the U/D Status word of the AT.

NOTE It is not necessary for the slave to set the U/D Busy bit true if it can respond with the requested data within the 10 communication cycle period allowed for the U/D Handshake bit to toggle.

After toggling the U/D Handshake bit, the slave shall verify the file type and block number and respond by setting the file type to the File Type bits and the block index number to the File Block Index field respectively, and by setting or clearing the File Transfer Error bit, and place data as appropriate in the Data Block field of the AT. Finally, the slave shall clear the U/D Busy bit in the U/D Status word to tell the master that the data is now valid. Only the U/D Handshake in the U/D Status word is valid when the U/D Busy bit is true. The master shall not initiate a new data transfer until the U/D Handshake bit in the slave AT matches that of the master and the U/D Busy bit is 0.

Subsequent data blocs shall be requested by incrementing the file block index of step 1 above and repeating steps 2 through 4. To transfer the entire file, this process shall be repeated until an error is reported or until the Final Block bit in the AT is set true.

In the event the slave returns an error condition on receipt of any file block, the master may request the same file block by leaving the File Block Index unchanged.

5.3.6.3 File block index in CP6 (MDT)

A file can be divided into File Blocs that can be uploaded from a slave one File Block at a time. The contents of a file, use and placement of the file by the slave are dependent upon manufacturer implementation. The File Block Index shall be used to indicate which File Block is to be uploaded. File blocs shall normally be requested sequentially beginning with File Block 0 and incrementing the block number until the entire file has been received as indicated by the Final Block bit in the AT.

5.4 AT DLPDU

5.4.1 Introduction

5.4.1.1 General AT telegram structure

In the AT, the data field shall have only one data record, which shall be sent from the device to the control unit cyclically, see Table 18. The data records of individual ATs shall be as specified in Table 19.

Table 18 – Data field of the acknowledge telegram

Frame part	Data field	Data type	Value/description
Acknowledge telegram	Real-time data slave #m	OCTET[see Table 19]	

Table 19– AT real-time data (for each device)

Frame part	Data field	Data type	Value/description
Real-time data slave #m	Device m status	OCTET[2]	
	Device m service INFO	OCTET[see 5.4.1.3]	
	Configurable real-time data	OCTET[see 5.4.4]	

5.4.1.2 Status m – status word of device XX

Table 20 describes the status word as it shall be.

Table 20 – Status word description (DLL)

Bit no,	Value	Meaning
15-8		Reserved for the application profile (e.g., IEC 61800-7-20x)
7-6		Reserved for application layer (IEC 61158-5)
5		Procedure command change bit
	0	No change in procedure command acknowledgement
	1	Changing procedure command acknowledgment
4		Reserved
3		Status command value processing
	0	Device ignores the command values
3	1	Device follows the command values
2		SVC error
	0	No error
	1	Error in SVC, error message in SVC INFO
1		Busy
	0	Step finished, slave ready for new step
	1	Step in process, new step not allowed
0		AHS
	toggle	SVC transport handshake of the slave (toggle bit)

5.4.1.3 Device service INFO m

The device service INFO field shall be 2, 4, 6 or 8 octets long in CP3 and CP4. In CP1 and CP2, it shall always be 2 octets long. The length shall be adjusted by the telegram type (S-0-0015) for CP3 and CP4.

The device service INFO field shall be the container for the non-cyclic data exchange from device XX to master which takes place in steps in special data fields of the telegram.

Figure 4 describes the device service info field as it shall be.

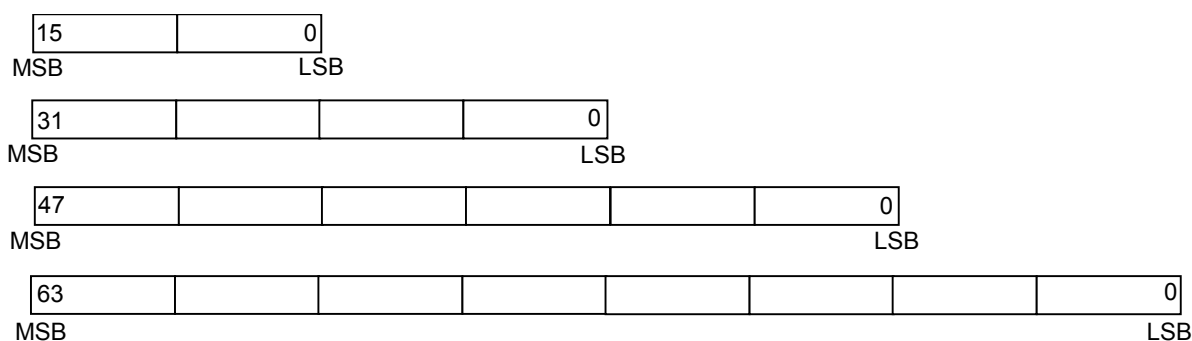


Figure 4 – Device service INFO field m

5.4.2 CP1 and CP2

In CP1 the addressed device shall respond by sending the identification AT (ID acknowledge telegram) as shown in Table 21.

Table 21 – Structure of the ID acknowledge telegram in CP1

Frame part	Data field	Data type	Value/description
AT data field ID acknowledge telegram in CP1	Status	OCTET[2]	
	Device service INFO	OCTET[2]	

Master service INFO (2 octets) and device service INFO (2 octets) shall be part of the ID request and ID acknowledge telegrams, but their content shall have no meaning during CP1.

Telegrams in CP2 shall have the same structure as in CP1, but the contents of the device service INFO shall now be valid.

5.4.3 CP3

The AT shall be structured as shown in Table 18 and Table 19. Only the fixed part of the data record shall be used. The configurable part of the data record does not care, but it shall have the number of octets required for cyclical operation.

The configurable real-time data field of the AT shall be used for transmitting individual real-time data to any device. Only operation data configured in two, four or eight octet length shall be used. The telegram type parameter S-0-0015 shall determine which operation data is included in the configurable real-time data field of the AT. The appropriate operation data for standard telegrams shall be defined by this parameter. The structure of the application telegram shall be determined by the configuration list labeled S-0-0016.

The structure of the telegram, which depends upon the application, shall be determined by the configuration list labeled S-0-0016.

Table 22 – Structure of the operation data of device m in acknowledge telegram

Frame part	Data field	Data type	Value/description
Device m Configurable real-time data	Operation data IDN ...	OCTET[depending upon IDN]	Number and length of operation data shall be as configured in IDN list S-0-0016 or by the selected standard telegram.
	Operation data IDN ...	OCTET[depending upon IDN]	
	Operation data IDN ...	OCTET[depending upon IDN]	
	...		
	Operation data IDN ...	OCTET[depending upon IDN]	

5.4.4 CP4

The AT shall be structured as in CP3 except that the configurable part of the data record shall be filled with actual values which shall be determined by the parameters transmitted in CP2.

5.4.5 CP5

5.4.5.1 Introduction

Table 23 show the form of the acknowledge telegram (AT) for CP5.

Table 23 – Structure of AT in CP5

Frame part	Data field	Data type	Value/description
AT data field AT in CP5	Status	OCTET[2]	unused
	Device INFO	OCTET[2]	unused
	Data Record	OCTET[see Table 24]	

The Status Word and the Device Service INFO shall be unused in CP5. The Data Record for the CP5 AT shall contain a 4 octet U/D Status word and a 4 octet File Block Index (see Table 23).

Table 24 – Structure of data record in AT in CP5

Frame part	Data field	Data type	Value/description
Data Record	U/D Status	OCTET[4]	
	File Block Index	OCTET[4]	

5.4.5.2 U/D status word in CP5

Table 25 defines the bits for the U/D Status word in the CP5 AT.

Table 25 – U/D status word in CP5

Bits	Value	Meaning
31		File type qualifier
	0	Type 16 specific file types
	1	User defined file types
30 - 16		File type identification number
15 - 4		(Reserved)
3		File transfer error
	0	No error
	1	Download error, error message in file block index in AT
2		U/D Busy
	0	Slave completed previous request
	1	Previous request accepted and in progress
1		Final Block
	0	Acknowledge: not last block of file transfer
	1	Acknowledge: final block of file transfer
0		U/D Handshake
	toggle	U/D Handshake of slave

If the slave sees a U/D Handshake bit in the MDT change from matching that of the slave AT to not matching and the Enable bit is set in the MDT, the slave shall save the type number sent in the File Type Qualifier and File Type fields, the block index number sent in the File Block Index field, and the data in the Data Block. If further processing of the file type, file block and data are necessary, the slave shall set the U/D Busy bit true and then toggle the U/D Handshake bit in the U/D Status word of the AT to indicate it has received the data and is processing it. The U/D Handshake bit in the AT shall be set to match that of the MDT in less

than or equal to 10 communication cycles or the master will assume a fault has occurred. The slave shall save all data in the MDT before toggling the U/D Handshake bit in the U/D Status Word.

The slave shall then verify that the File Type Qualifier, File Type, File Block Index and data from the MDT are valid. If no error is found, the data transferred shall be applied as appropriate in the slave. When the slave has completed processing the file data, the file type number and data block number shall be returned in the File Type bits and File Block Index fields of the AT respectively. Clearing the U/D Busy bit shall notify the master that the operation is complete, and that the File Type, File Block Number and the File transfer error bit in the AT are valid and the slave is free to accept more data.

If the Final Block bit was set in the MDT the slave shall take appropriate action for the final block of data transfer in the slave. This action is not part of this specification.

If either the file type number or the file block number are invalid or the data field contains unexpected or erroneous data, the slave shall set the File transfer error bit true and place a 32 bit error code in the File Block Number field in the AT. Error codes are defined in Table 26.

5.4.5.3 File block index in CP5 (AT)

Before the slave toggles the U/D Handshake bit in the AT to match the MDT and sets the U/D Busy bit to 0, it shall set the File Block Index field to the value of the File Type Qualifier and File Block Index received in the MDT. The master can use this value to verify the correct block is being transferred.

If an error occurs, the slave shall replace the File Block Index with a 32 bit error code. The Table 26 defines the error message in the File Block Index in the CP5 AT.

Table 26 – File block index in CP5

Bits	Value	Meaning
31 -16		User defined error message
15 - 4		(Reserved)
3		File checksum error
	0	No error
	1	Error
2		File type error
	0	No error
	1	File type not supported
1		File block data error
	0	No error
	1	Data transferred not valid
0		File block index error
	0	No error
	1	Invalid file block index number

5.4.5.4 U/D control word and U/D status word handshaking in CP5

Figure 5 shows the functional relationship between the Enable and U/D Handshake bits in the CP5 MDT and the U/D Busy and the U/D Handshake bit in the CP5 AT.

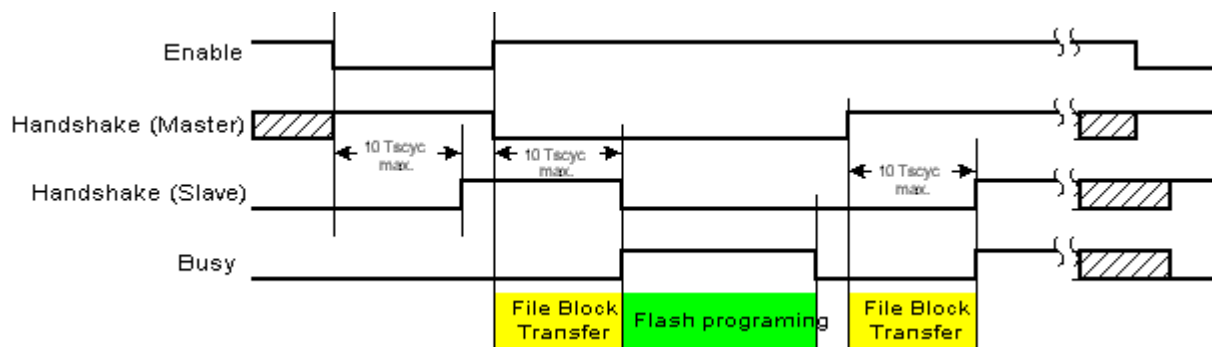


Figure 5 – Timing of U/D bits in CP5

5.4.6 CP6

5.4.6.1 Introduction

Table 27 shows the form of the acknowledge telegram (AT) for CP6.

Table 27 – Structure of AT in CP6

Frame part	Data field	Data type	Value/description
AT data field AT in CP6	Status	OCTET[2]	Unused
	Device INFO	OCTET[2]	Unused
	Data Record	OCTET[see Table 29]	

The Status Word and the Device Service INFO shall be unused in CP6. The Data Record for the CP6 AT shall be as specified in Table 28. The File Block size shall be set by the transmission rate as shown in Table 29.

Table 28 – Structure of data record in AT in CP6

Frame part	Data field	Data type	Value/description
Data Record	U/D Status	OCTET[4]	
	File Block Index	OCTET[4]	
	File Block	OCTET[see Table 29]	

Table 29 – File block size in CP6

Transmission rate (Mbit/s)	File block size (octets)	MDT length (octets)	AT length (octets)
2	128	12	140
4	256	12	268
8	512	12	524
16	1 024	12	1 036

5.4.6.2 U/D status word in CP6

The Table 30 defines the bits for the U/D Status Word in the CP6 AT.

Table 30 – U/D status word in CP6

Bits	Value	Meaning
31		File type qualifier
	0	Type 16 specific file types
	1	User defined file types
30 - 16		File type identification number
15 - 4		(Reserved)
3		File transfer error
	0	No error
	1	Upload error, error message in file block index in AT
2		U/D Busy
	0	Slave completed previous request
	1	Previous request accepted and in progress
1		Final Block
	0	Not last block of file being transferred
	1	Final block of file being transferred
0		U/D Handshake
	toggle	U/D Handshake of slave

If the slave sees a U/D Handshake bit in the MDT change from matching that of the slave AT to not matching and the Enable bit is set in the MDT, the slave shall save the type number sent in the File Type Qualifier and File Type fields and the block index number sent in the File Block Index field. If the file type number and the block index are supported by the slave, the slave shall fill the Data Block field with the requested data and toggle the U/D Handshake bit in the AT to match that of the MDT. If the time required to fill the data field exceeds 10 communication cycles, the slave shall set the U/D Busy bit and toggle the U/D Handshake bit before attempting to fill the data field. When the data field is updated, the slave shall then set the U/D Busy bit to 0 to signal the master that the data is now valid. In either case, the U/D Handshake bit in the AT shall be set to match that of the MDT in 10 or less communication cycles or the master will assume a fault has occurred.

The slave shall set the Final Block bit in the U/D Status word to indicate the final block of the file. Definition of Final File block is not part of this specification.

If either the file type number or the file block number is invalid, the slave shall set the File Transfer Error bit in the AT as appropriate and place a 32 bit error code in the File Block Number field in the AT. Error codes are defined in Table 31.

The master shall only read data in the U/D Status word and the Data field if the U/D Handshake bit matches that of the master and the U/D Busy bit is 0.

5.4.6.3 File block index and file block in CP6 (AT)

Before the slave toggles the U/D Handshake bit in the AT to match the MDT and sets the U/D Busy bit to 0, it shall set the File Block Index field to the value of the File Type Qualifier and File Block Index received in the MDT. The master can use this value to verify the correct block is being transferred.

If an error occurred, the slave shall replace the File Block Index with a 32 bit error code. The Table 31 defines the error message in the File Block Index in the CP6 AT.

Table 31 – File block index in CP6

Bits	Value	Meaning
31 -16		User defined error message
15 - 3		(Reserved)
2		File type error
	0	No error
	1	File type not supported
1		(Reserved)
0		File block index error
	0	No error
	1	Invalid file block index number

5.4.6.4 U/D control word and U/D status word handshaking in CP6

Figure 6 shows the functional relationship between the Enable and U/D Handshake bits in the CP6 MDT and the U/D Busy and the U/D Handshake bit in the CP6 AT.

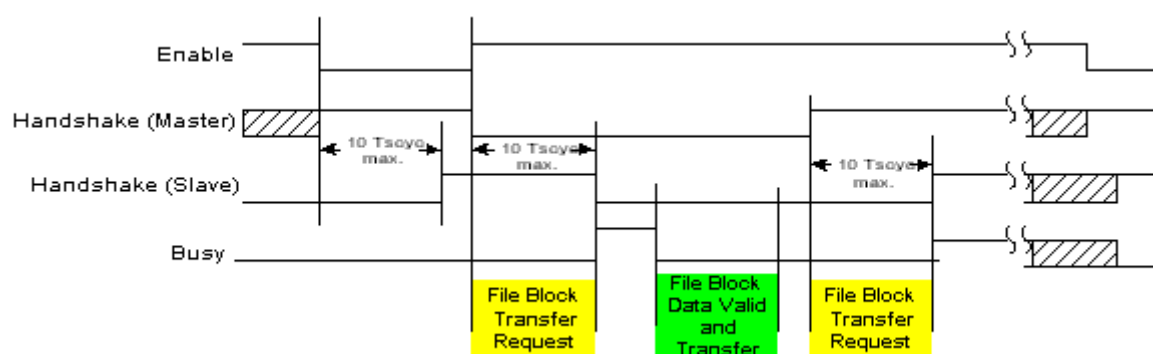


Figure 6 – Timing of U/D bits in CP6

6 Network management methods

6.1 Overview

DL-management procedures are functionally processed in response to DL-management service requests submitted by the DL-user and events caused by the network.

6.2 Enable and disable cyclic communication

6.2.1 Introduction

Upon an Initiate_cyclic_communication (ICC) request by the DL user in the master device the so-called phase upshift is initiated.

A Notify_cyclic_communication (NCC) indication is generated for the DL user in the slave device if the phase upshift has been successfully completed.

Upon a Disable_cyclic_communication (DCC) request by the DL user in the master device the so-called phase downshift is initiated.

A Notify_cyclic_communication_disabled (NCCD) indication is generated for the DL user in the slave device if the cyclic communication has been disabled.

A Notify_error (NER) indication is generated for the DL user in a master and a slave device if an error has occurred in the cyclic communication.

6.2.2 Communication phases (CP)

6.2.2.1 Introduction

Initialization shall be divided into five communication phases (CPs):

- network initialization shall always begin with CP0;
- CP0 and CP1 shall be used for recognizing the participating devices;
- in CP2, the timing and data structure of the protocols for normal operation shall be prepared;
- in CP3, the station synchronization and the cyclic data transmission shall be operational;
- in CP4, the initialization process shall be over and the network shall be in normal operation. CP4 shall be similar to CP3 as far as communication is concerned, but valid application-specific data shall be transmitted.

It shall also be possible to enter CP0 from any higher phase. It shall not be possible to enter other phases except when leaving the previous one in ascending order.

The master shall initiate a specific CP by setting the INFO octet of the MST (see 5.2). The slaves shall follow accordingly. Only in the case of a communication error shall the slaves switch to CP0.

6.2.2.2 Communication phase 0 (CP0)

6.2.2.2.1 General

After all slaves in the network have been powered up, and after internal checks are error-free, all slaves shall be operating in repeater mode only. The master shall send MSTs and monitor its receiver for receipt in order to verify network closure.

During CP0, the master shall only send the MSTs. The slaves shall not send any telegram.

6.2.2.2.2 Leaving CP0

The master shall wait for its MST to be received. As soon as the master has received its own MSTs back for at least 10 successive cycles, which means that the network is closed and that all the slaves in the network are in the repeater mode, the master shall initiate CP1.

If this procedure cannot be achieved within the time set by the master, the master shall remain in CP0 and generate a message. The scope of the message and at what point it has to be activated is a function of the control unit.

If CP0 is initiated as a response to a previous communication error, a routine in the master may be used to cause an automatic advance routine to CP2 with the possibility of error diagnostics, as specified by its manufacturer or depending upon configuration.

6.2.2.3 Communication phase 1 (CP1)

In CP1, any data exchange during one cycle shall only be possible between the master and one device. CP1 shall be used for recognizing the devices connected to the network. To do so, the master shall address each device specifically with the device address. The device shall answer to a MDT which is addressed to it by sending an AT in the next cycle.

The required addresses shall be storable in the control unit to verify that all devices are present as required by the configuration. It shall also be possible to find all devices in the

network by calling all allowed device addresses and waiting for an answer. The master may compare the detected device addresses with the device addresses that it is expecting to find, and then evaluate deviations (e.g., generate an error message).

The address $XX = 0$ shall not be used in the inquiry. Devices that are not participating in the communication shall use this address as their address (see 5.1.3). Devices that are not being addressed in CP1 and whose address is not 0 shall behave like devices with the address 0. No device shall react in CP1 when address 0 or 255 is queried.

6.2.2.4 Operational sequence in phase 1 (CP1)

6.2.2.4.1 General

At the beginning of CP1, it is not certain that the physical slave is ready to receive the MDT. It might happen that a slave's repeater operates (the network is closed) but start-up routines are still being processed internally. Thus a particular device address might have to be queried several times. The master shall begin with the lowest address in the network or uses any other strategy, depending upon configuration, and shall expect a response within the HS timeout (see 9.3).

The master shall repeat this request until the addressed device acknowledges or until the HS timeout. If a device does not respond, it is recommended that it be addressed again after some time is elapsed.

6.2.2.4.2 Leaving CP1

After the master has identified the devices on the network and no error has occurred, the MST INFO field shall be used to initiate CP2.

If the device identification time is exceeded or deviations to the stored device addresses are detected, the initialization shall not be continued. The control unit shall evaluate deviations (e.g., generate an error message).

6.2.2.5 Communication phase 2 (CP2)

6.2.2.5.1 General

During CP2, the devices shall be addressed specifically by their addresses. For CP2 and higher phases, they shall support complete service channel functionality.

As a minimum, the communication parameters transmission starting times and transfer timeslots required for CP3 and CP4 and the parameters for determining the length and the contents of the MDT and ATs shall be transmitted to the devices. The slave shows in "IDN-list of operation data for CP2" which data in CP2 shall be transferred (see S-0-0018).

The entire information exchange shall take place via the mechanisms of the service channel. The reliability of transmission is guaranteed by the MHS and AHS bits as well as the HS timeout. Further parameter exchanges can take place in CP2 or CP3. No device shall react in CP2 if the addresses 0 or 255 are queried.

6.2.2.5.2 Leaving CP2

The transition from CP2 to CP3 shall be performed according to the following procedure.

- a) The master shall activate the procedure command "CP3 transition check" as defined in S-0-0127.
- b) The slave shall then determine the validity of the parameters for CP3.
- c) The slave shall acknowledge the procedure command positively (e.g., "Procedure command executed correctly").

- d) After the positive procedure command acknowledgment, the master shall delete the procedure command in the slave.
- e) The master shall then switch to CP3.

If the slave is not yet ready to switch over (e.g., the parameters required for CP3 have not yet been completely calculated), the slave shall set the procedure command acknowledgment “procedure command not yet executed”.

If there are additional invalid parameters still present after the procedure command has been processed, the slave shall respond with the procedure command acknowledgment “Error, procedure command execution impossible”. In this case, the master shall remain in CP2 and, depending on its capabilities, try to set again the parameters identified as invalid or to send an error message to allow further initialization by means of an operator intervention. If a fault occurs, the slave shall save the IDNs of the invalid data into the “IDN-list of invalid operation data for CP2” (see S-0-0021).

After the master has transmitted further parameters (depending on S-0-0021) to the slave in CP2, the procedure command “CP 3 transition check” shall be activated once more.

The validity check of the parameters by the slave shall refer only to general criteria (e.g., minimum, maximum). It shall not recognize if all parameters that have been transmitted by the master are correct with respect to the master data and the total installation. This means that even if a slave acknowledges the “CP3 transition check” positively, there can be incorrect communication parameters with respect to the total installation which can lead to a disruption of the communication.

If CP2 was attained by an automatic advance routine after an error, this error shall be corrected first before a transition to CP3 can take place.

Depending upon configuration the master may also switch to CP0 in case of communication error or human intervention (e.g., the operator).

6.2.2.6 Communication phase 3 (CP3)

6.2.2.6.1 General

In the first cycle CP3, it shall not be necessary to send an AT.

Starting with CP3, the exchange of data shall be done via the telegrams defined for CP4. Also the timeslots for cyclic operation shall be used. The MDT shall be sent with the broadcast address.

During CP3, the parameters for the devices shall be set by means of the service channel. The slave shall show in “IDN-list of operation data for CP3” which data in CP3 needs to be transferred (see S-0-0019). Transmission reliability for the service channel shall be guaranteed by the MHS and AHS-bits as well as the HS timeout.

6.2.2.6.2 Leaving CP3

The transition from CP3 to CP4 shall be performed according to the following procedure.

- a) The master shall activate the procedure command “CP4 transition check” as defined in S-0-0128.
- b) The slave shall then determine the validity of the parameters for CP4.
- c) Afterwards, the slave shall complete the processing of the parameters that are required for operating the slave.
- d) The slave shall then activate the synchronization.

- e) And finally, the slave shall acknowledge the procedure command positively (e.g., “procedure command executed correctly”).
- f) After receiving the positive procedure command acknowledgment, the master shall delete the procedure command in the slave.
- g) The master shall then switch to CP4.

If the slave is not yet ready to switch over (e.g., the parameters required for operating the slave have not yet been completely calculated), it shall set the procedure command acknowledgment – “procedure command not yet executed”.

If there are additional invalid parameters still present after the procedure command has been processed, the slave shall respond with the procedure command acknowledgment “Error, procedure command execution impossible”. In this case, the master shall remain in CP3 and, depending on the capabilities of the master, try to re-establish the parameters identified as invalid or send an error message indicating that human intervention (e.g., operator) is required. In a faulty case, the slave shall save the IDNs of the invalid data into the “IDN-list of invalid operation data for CP3” (see S-0-0022).

After the master has transmitted further parameters (depending on S-0-0022) to the slave in CP3, the procedure command “CP 4 transition check” shall to be activated once more.

Depending upon configuration the master can also switch to CP0 in case of communication errors or human intervention (e.g., the operator).

6.2.2.7 Communication phase 4 (CP4) – end of initialization

6.2.2.7.1 General

Upon switching to CP4 the initialization is complete.

6.2.2.7.2 Leaving communication phase 4 (CP4)

The only possibility of leaving CP4 shall be a return to CP0. The reason for this can be communication faults or human intervention (e.g., operator). Any slave which recognizes CP0 shall shut down itself in the best possible manner. The method of shutting down the slaves is part of the application profiles (e.g., IEC 61800-7-20x).

6.2.2.7.3 Switching to communication phase 0 (CP0)

When switching the control unit from communication phase 3 or 4 (CP3/4) to communication phase 0 (CP0), after switching, within two communication cycles, MST shall be sent with phase 0 by the control unit. If this is not the case, the devices shall recognize MST-failure in the CP3 or CP4. The first MST of the CP0 shall be in the raster of the communication cycle time.

Figure 7 shows the three possible cases that are as follow:

- **Case 1:** If the master changes over within 1 communication cycle time and sends MST with phase 0 immediately, without interruption, then the slave does not see any MST failure and shall therefore not recognize any MST error.
- **Case 2:** If the master needs more time and changes over within 2 communication cycle times, then one MST is missing before the master resumes sending MSTs with phase 0. The slave notices one MST failure, but shall not recognize any double MST failure.
- **Case 3 - Error:** If the master needs further more time and changes over within ≥ 3 communication cycle times, then ≥ 2 MST are missing before the master resumes sending MSTs with phase 0. The slave shall recognize a double MST failure and generate an error of class 1 diagnostics.

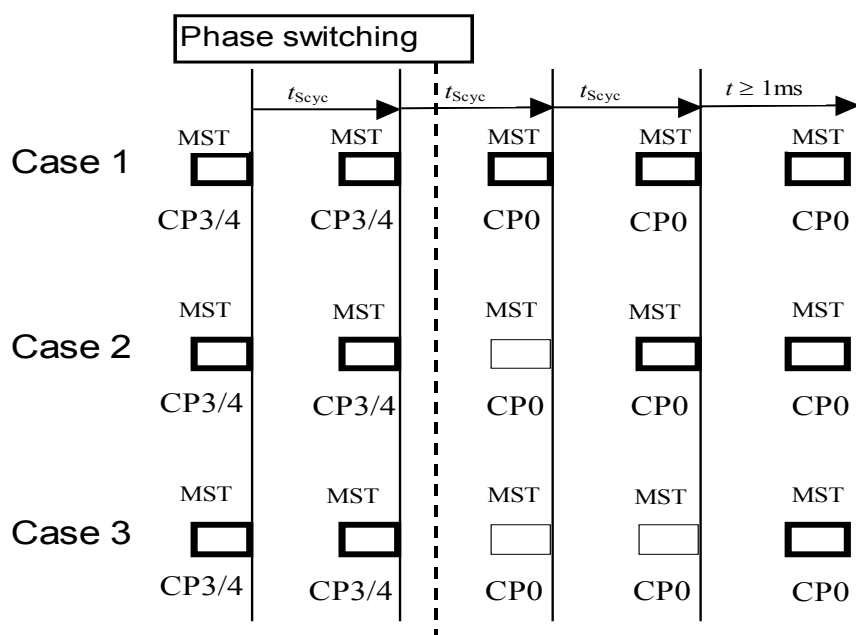


Figure 7 – Switching to CP0

6.3 File transfer

A network shall provide for specific methods for the download and upload of files to and from a slave, as specified in this subclause. During the download process, a binary data file of arbitrary length shall be transferred from the master to the slave. During upload, binary data shall be recovered from the slave.

File lengths, file contents, how the file is to be used, and where the file is to be located in the device's memory space is not part of this specification. A file may contain a header defining how the file is to be used (file type, size, location, etc.). The specification of a header is left to the manufacturer. This means that files are not necessarily interchangeable between slaves of different manufacturers.

Two additional communication phases shall be used:

- phase 5 (CP5), which shall be used to download files and is characterized by a large file block in the MDT;
- phase 6 (CP6), which shall be used to upload files and is characterized by a large file block in the AT.

Phases 5 and 6 shall only be reached from CP0. Figure 8 shows the allowed communication phase transitions. The communication phase can be returned to CP0 from any phase.

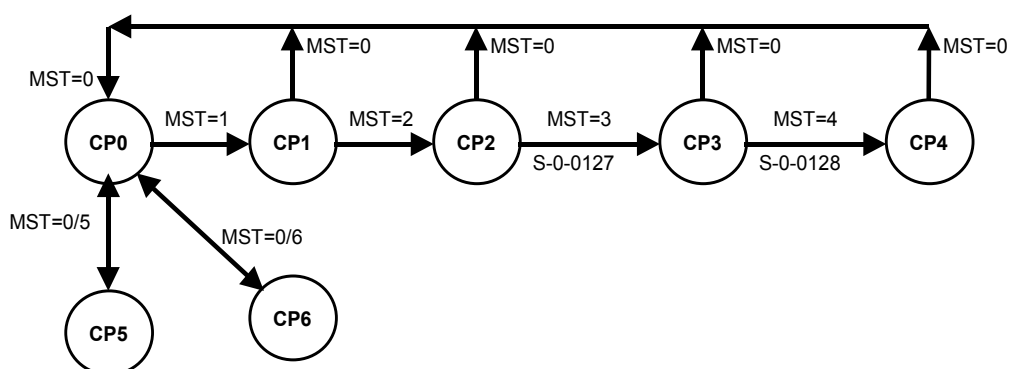


Figure 8 – Phase transitions

In CP5, data exchange in any one cycle shall be possible only between the master and one slave. CP5 shall be used for the download of files to slaves. To do so, the master shall transmit an MDT with a specific slave address. The slave shall respond by transmitting its status in an AT. The master can identify a slave by checking the address field in the AT.

The addresses $XX = 0$ and $XX = 255$ shall not be used in the transmission of the MDT. No slave shall react in CP5 if address 0 or 255 is used in the transmission of the MDT.

When leaving communication phase 5 (CP5 to CP0 transition) it is anticipated that some slaves will not be able to advance from CP0 to CP1 following CP5 download. Should this be the case, the slave shall report an error if the CP0 to CP1 transition is attempted. In addition, operation manuals for the slave shall detail the required procedure for returning the slave to normal operation.

CP6 data exchange in any one cycle shall be possible only between the master and one slave. CP6 shall be used to upload of files from slaves. To do so, the master shall transmit an MDT with a specific slave address. The slave shall respond by transmitting its status in an AT. The master can identify a slave by checking the address field in the AT.

The addresses $XX = 0$ and $X = 255$ shall not be used in the transmission of the MDT. No slave shall react in CP6 if address 0 or 255 is used in the transmission of the MDT.

6.4 Status procedures

Upon a Get_Device_Status (GDS) request by the DL user in the master device the status word of the specified device is returned to the DL user.

Upon a Set_Device_Status (SDS) request by the DL user in the master device the control word of the specified device is set.

Upon a Get_Network_Status (GNS) request by the DL user in the master device the status of the network is returned to the DL user.

7 Data transmission methods

7.1 Overview

Data transmission methods are the means by which a DLE performs its functions and affects the behavior of the DL-protocol. Methods are initiated, executed and terminated under the control of invoked services, as specified in the Type 18 DL-service

7.2 SVC

7.2.1 Introduction

7.2.1.1 SVC handling

Acyclic data is exchanged between a master and a slave device upon a Read (RD) request initiated by the DL user in a master device.

Acyclic data is exchanged between a master and a slave device upon a Read (RD) request initiated by the DL user in a master device.

In addition to the cyclic transmission of data, Type 16 shall provide the ability to transmit non-cyclic data. To transmit this data, the device service INFO field shall be reserved for the service channel in the MDT (see 5.3.1.3) and in the AT (see 5.4.1.3). Special control and status bits in the control word of the MDT or the status word of the AT shall be used to control

execution in the service channel. Therefore, the master shall be able to support a separate service channel for every connected device.

With a SVC transmission, the following operations shall be possible:

- initialization of the Type 16 communication;
- transmission of all elements of a data block;
- transmission of procedure commands;
- changing limit values on demand;
- changing control loop parameters on demand;
- obtaining detailed status messages from a device;
- diagnostic functions;

Any SVC transmission shall always be initiated and controlled by the master. The operations, “read element” or “write element”, shall be from the perspective of the master. All operations shall always relate to the last transmitted IDN.

The service channel shall be initialized during CP1 and be functional for the remainder of the communication phases.

The SVC transport of operation data or of a procedure command shall be handled via a predetermined handling and proceeding sequence (see Figure 9 and Figure 10) for individual actions. The master shall follow strictly the outline of these diagrams.

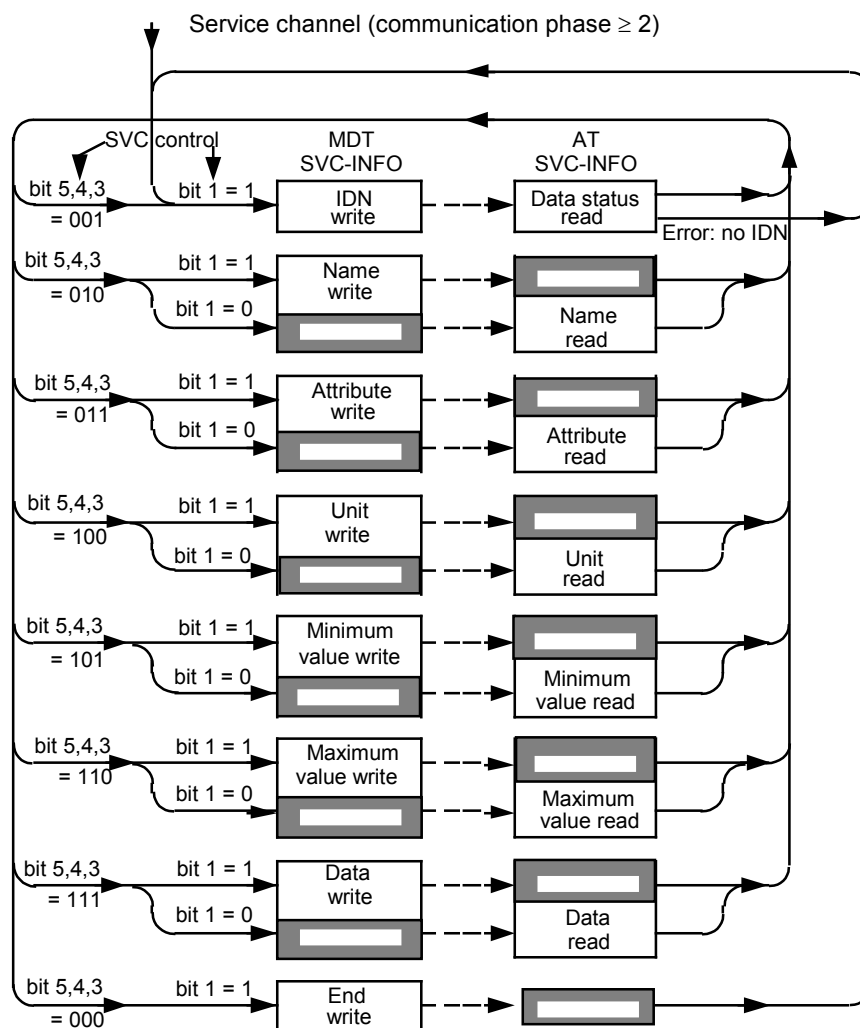


Figure 9 – Service channel handling diagram

7.2.1.2 Selection of IDN

The transmission shall start with the opening of the service channel by sending the IDN of the data block (SVC control, bits 5, 4, 3 = 001, element 1). The slave shall respond by writing the IDN with the data status or the procedure command acknowledgment.

7.2.1.3 Selection of data block element

During the next step, the master shall indicate which elements of the data block shall be processed. For this purpose, the master shall set bits 5, 4 and 3 accordingly in the SVC control.

7.2.1.4 Read/Write

Following this, the master shall indicate in bit 1 whether the element will be read or written to. While writing, the SVC INFO field of the MDT shall be filled with the appropriate data for the slave (contents of the AT SVC INFO field are invalid). If reading is selected, the slave shall insert the appropriate data in the SVC INFO field of the AT (contents of the SVC INFO field of the MDT are invalid).

7.2.1.5 Transmission steps

Depending on the length of the data block elements which need to be transmitted and of the length of the SVC INFO field, several steps shall be performed. Every step shall transport four octets of data.

Table 32 shows the necessary steps for the individual elements of a data block.

Table 32 – List of IDNs element and step numbers

Element number	Description	Requirement	Number of steps	
1	IDN	Mandatory	1	
2	Name	Optional	1 to 16	
3	Attribute	Mandatory	1	
4	Unit	Optional	1 to 4	
5	Minimum input value	Optional	1or 2	
6	Maximum input value	Optional	1or 2	
7	Operation data	Mandatory	Fixed length:	1 or 2
			Variable length:	1 to 16 384
Closing the service channel			1	

The master shall indicate in bit 2 of the SVC control a transmission in progress (bit 2 = 0) or the transmission of the last 4 octets (bit 2 = 1). A transport with just one step shall immediately be set by the master as the last transmission (bit 2 = 1).

The error messages “element transmission too short” or “element transmission too long” shall be executed by the slave only if the length of the actual transmitted element is not in coincidence with the states of bit 2 in the SVC control.

7.2.1.6 End of transmission

The SVC transmission of operation data or a procedure command shall end with the transmission of the IDN for the next operation data or procedure command.

7.2.1.7 Changing of data block element

Changing the data block element shall be possible without an error message only if the following bits have the status given in Table 33.

Table 33 – Condition for modifying data block elements

Information	SVC control bit	SVC status bit	bit value
Transmission in progress	bit 2		0
Handshake bits equal	bit 0	bit 0	MHS = AHS
Busy		bit 1	0
SVC valid		bit 3	1

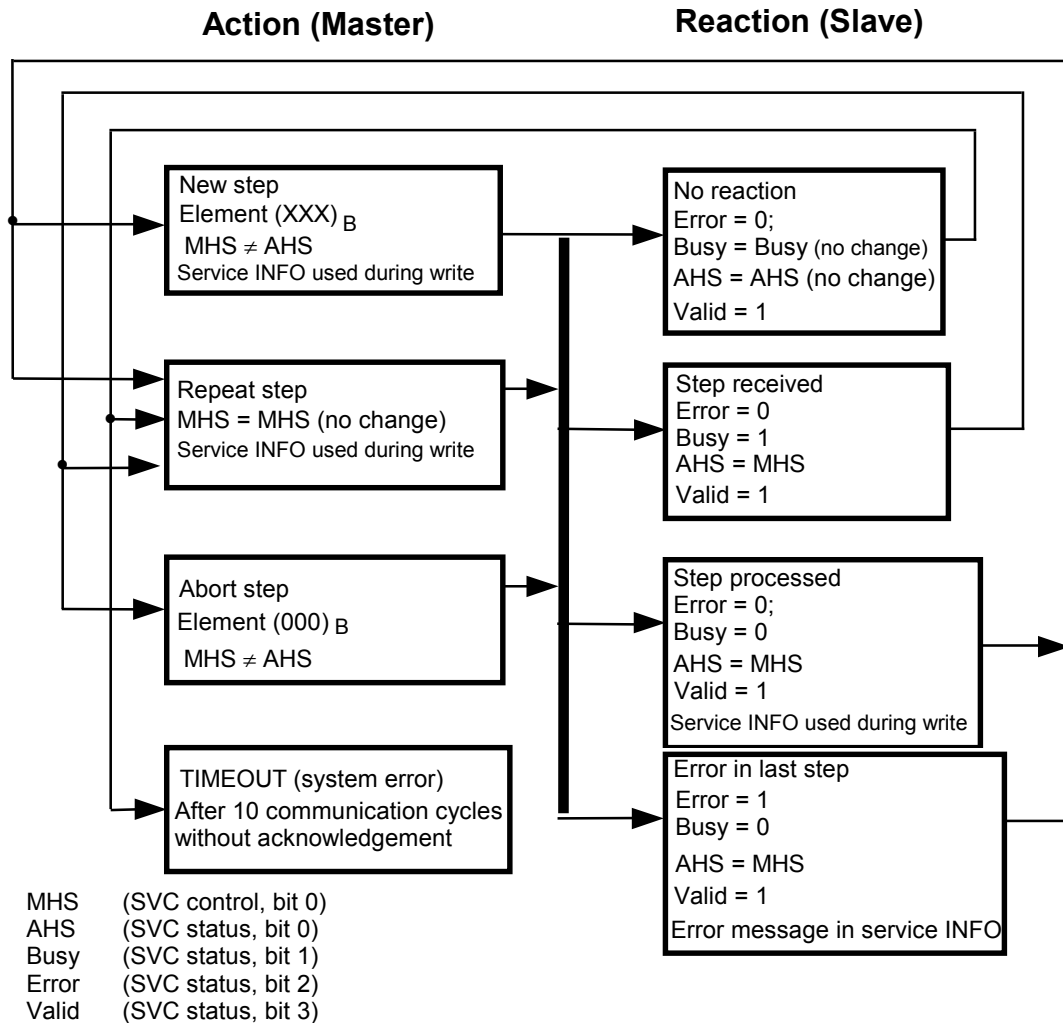


Figure 10 – Communication step proceeding diagram

7.2.1.8 SVC valid

The slave shall set “SVC valid” (SVC status, bit 3) to 1 (valid) as soon as it has finished handling the required service channel action. It shall set it back to 0 (not valid) if it is unable to handle the master’s demand (MHS ≠ AHS). In a ring topology, the slave may handle the SVC enquiries either on the primary or on the secondary channel, depending on configuration. In a line topology, the slave shall handle the SVC enquiries only on one channel (primary or secondary) as required by the master.

The master shall evaluate the slave’s SVC answer only if it reads “SVC valid” (SVC status, bit 3). It shall not evaluate it if “SVC valid” = 0 (invalid). The master shall scan the SVC in the primary or secondary depending on the topology.

The time-out of SVC valid is the same as HS time-out (see 7.2.1.9).

7.2.1.9 Handshake bits

During SVC transmissions, the transport of every step shall be secured by two service transport handshake bits. These shall be the bits 0 in the SVC control (MHS) and in the SVC status (AHS).

For every new step during the transmission, the master shall toggle the MHS-bit. The slave shall recognize by the toggled MHS-bit that a new step needs to be executed. After the slave