

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Industrial communication networks – Fieldbus specifications –
Part 6-12: Application layer protocol specification – Type 12 elements**

**Réseaux de communication industriels – Spécifications des bus de terrain –
Partie 6-12: Spécification du protocole de la couche application – Éléments
de type 12**



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INTERNATIONAL
ELECTROTECHNICAL
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INTERNATIONALE

ICS 25.040.40; 35.100.70; 35.110

ISBN 978-2-8322-9324-9

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FIELDBUS SPECIFICATIONS –****Part 6-12: Application layer protocol specification –
Type 12 elements**

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NOTE Combinations of protocol types are specified in IEC 61784-1 and IEC 61784-2.

International Standard IEC 61158-6-12 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This fourth edition cancels and replaces the third edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- technical corrections; and
- editorial improvements for clarification.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
65C/948/FDIS	65C/956/RVD

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

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

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

The committee has decided that the contents of this publication will remain unchanged until the stability 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- withdrawn,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.

INTRODUCTION

This document 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 61158-1.

The application protocol provides the application service by making use of the services available from the data-link or other immediately lower layer. The primary aim of this document is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer application entities (AEs) 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:

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

This document is concerned, in particular, with the communication and interworking of sensors, effectors and other automation devices. By using this document 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 6-12: Application layer protocol specification – Type 12 elements

1 Scope

1.1 General

The Fieldbus Application Layer (FAL) provides user programs with a means to access the fieldbus communication environment. In this respect, the FAL can be viewed as a “window between corresponding application programs.”

This part of IEC 61158 provides common elements for basic time-critical and non-time-critical messaging communications between application programs in an automation environment and material specific to Type 12 fieldbus. The term “time-critical” is used to represent the presence of a time-window, within which one or more specified actions are required to be completed with some defined level of certainty. Failure to complete specified actions within the time window risks failure of the applications requesting the actions, with attendant risk to equipment, plant and possibly human life.

This International Standard defines in an abstract way the externally visible behavior provided by the different Types of the fieldbus Application Layer in terms of

- a) the abstract syntax defining the application layer protocol data units conveyed between communicating application entities,
- b) the transfer syntax defining the application layer protocol data units conveyed between communicating application entities,
- c) the application context state machine defining the application service behavior visible between communicating application entities; and
- d) the application relationship state machines defining the communication behavior visible between communicating application entities; and.

The purpose of this document is to define the protocol provided to

- a) define the wire-representation of the service primitives defined in IEC 61158-5-12, and
- b) define the externally visible behavior associated with their transfer.

This document specifies the protocol of the IEC fieldbus Application Layer, in conformance with the OSI Basic Reference Model (ISO/IEC 7498) and the OSI Application Layer Structure (ISO/IEC 9545).

FAL services and protocols are provided by FAL application-entities (AE) contained within the application processes. The FAL AE is composed of a set of object-oriented Application Service Elements (ASEs) and a Layer Management Entity (LME) that manages the AE. The ASEs provide communication services that operate on a set of related application process object (APO) classes. One of the FAL ASEs is a management ASE that provides a common set of services for the management of the instances of FAL classes.

Although these services specify, from the perspective of applications, how request and responses are issued and delivered, they do not include a specification of what the requesting and responding applications are to do with them. That is, the behavioral aspects of the applications are not specified; only a definition of what requests and responses they can

send/receive is specified. This permits greater flexibility to the FAL users in standardizing such object behavior. In addition to these services, some supporting services are also defined in this document to provide access to the FAL to control certain aspects of its operation.

1.2 Specifications

The principal objective of this document is to specify the syntax and behavior of the application layer protocol that conveys the application layer services defined in IEC 61158-5-12.

A secondary objective is to provide migration paths from previously-existing industrial communications protocols. It is this latter objective which gives rise to the diversity of protocols standardized in subparts of IEC 61158-6.

1.3 Conformance

This document does not specify individual implementations or products, nor does it constrain the implementations of application layer entities within industrial automation systems.

There is no conformance of equipment to the application layer service definition standard. Instead, conformance is achieved through implementation of this application layer protocol specification.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE All parts of the IEC 61158 series, as well as IEC 61784-1 and IEC 61784-2 are maintained simultaneously. Cross-references to these documents within the text therefore refer to the editions as dated in this list of normative references.

IEC 61158-3-12, *Industrial communication networks – Fieldbus specifications – Part 3-12: Data-link layer service definition – Type 12 elements*

IEC 61158-5-12, *Industrial communication networks – Fieldbus specifications – Part 5-12: Application layer service definition – Type 12 elements*

IEC 61158-6 (all parts), *Industrial communication networks – Fieldbus specifications – Part 6: Application layer protocol specification*

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

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

ISO/IEC/IEEE 8802-3, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet*

ISO/IEC 9545, *Information technology – Open Systems Interconnection – Application Layer structure*

ISO/IEC 9899, *Information technology – Programming languages – C*

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

ISO/IEC/IEEE 60559, *Information technology – Microprocessor Systems – Floating-Point arithmetic*

IEEE Std 802.1D, *IEEE standard for Local and metropolitan area networks – Common specifications – Media access control (MAC) Bridges*; available at <http://www.ieee.org> [viewed 2018-09-11]

IEEE Std 802.1Q, *IEEE standard for Local and metropolitan area networks – Bridges and Bridged Networks*; available at <http://www.ieee.org> [viewed 2018-09-11]

IETF RFC 768, *User Datagram Protocol*; available at <http://www.ietf.org> [viewed 2018-09-11]

IETF RFC 791, *Internet Protocol darpa internet program protocol specification*; available at <http://www.ietf.org> [viewed 2018-09-11]

IETF RFC 826, *An Ethernet Address Resolution Protocol or Converting Network Protocol Addresses to 48.bit Ethernet Address for Transmission on Ethernet Hardware*; available at <http://www.ietf.org> [viewed 2018-09-11]

3 Terms, definitions, symbols, abbreviations and conventions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 Reference model terms and definitions

This document 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	correspondent (N)-entities correspondent AL-entities (N=7)	[ISO/IEC 7498-1]
3.1.2	(N)-entity AL-entity (N=7)	[ISO/IEC 7498-1]
3.1.3	(N)-layer AL-layer (N=7)	[ISO/IEC 7498-1]
3.1.4	layer-management	[ISO/IEC 7498-1]
3.1.5	peer-entities	[ISO/IEC 7498-1]
3.1.6	primitive name	[ISO/IEC 7498-3]
3.1.7	AL-protocol	[ISO/IEC 7498-1]
3.1.8	AL-protocol-data-unit	[ISO/IEC 7498-1]
3.1.9	Reset	[ISO/IEC 7498-1]
3.1.10	routing	[ISO/IEC 7498-1]
3.1.11	segmenting	[ISO/IEC 7498-1]
3.1.12	(N)-service AL-service (N=7)	[ISO/IEC 7498-1]
3.1.13	AL-service-data-unit	[ISO/IEC 7498-1]
3.1.14	AL-simplex-transmission	[ISO/IEC 7498-1]
3.1.15	AL-subsystem	[ISO/IEC 7498-1]
3.1.16	systems-management	[ISO/IEC 7498-1]
3.1.17	AL-user-data	[ISO/IEC 7498-1]

3.2 Service convention terms and definitions

This document 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	AL-service-primitive; primitive
3.2.6	AL-service-provider
3.2.7	AL-service-user
3.2.8	indication (primitive); acceptor.deliver (primitive)
3.2.9	request (primitive); requestor.submit (primitive)
3.2.10	requestor
3.2.11	response (primitive); acceptor.submit (primitive)
3.2.12	submit (primitive)
3.2.13	symmetrical service

3.3 Application layer definitions

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

3.3.1

application

function or data structure for which data is consumed or produced

3.3.2

application objects

multiple object classes that manage and provide a run time exchange of messages across the network and within the network device

3.3.3

application process

part of a distributed application on a network, which is located on one device and unambiguously addressed

3.3.4

application relationship

cooperative association between two or more application-entity-invocations for the purpose of exchange of information and coordination of their joint operation

Note 1 to entry: This relationship is activated either by the exchange of application-protocol-data-units or as a result of preconfiguration activities.

3.3.5

attribute

description of an externally visible characteristic or feature of an object

Note 1 to entry: The attributes of an object contain information about variable portions of an object. Typically, they provide status information or govern the operation of an object. Attributes may also affect the behavior of an object. Attributes are divided into class attributes and instance attributes.

3.3.6

basic slave

slave device that supports only physical addressing of data

3.3.7

behavior

indication of how an object responds to particular events

3.3.8

bit

unit of information consisting of a 1 or a 0

Note 1 to entry: This is the smallest data unit that can be transmitted.

3.3.9

channel

representation of a single physical or logical management object of a slave to control conveyance of data

3.3.10

client

<object> object which uses the services of another (server) object to perform a task

3.3.11

client

<message> initiator of a message to which a server reacts

3.3.12

clock synchroization

representation of a sequence of interactions to synchronize the clocks of all time receivers by a time master

3.3.13

communication object

component that manages and provides a run time exchange of messages across the network

3.3.14

connection

logical binding between two application objects within the same or different devices

3.3.15

consume

act of receiving data from a provider

3.3.16

consumer

node or sink receiving data from a provider

3.3.17

conveyance path

unidirectional flow of APDUs across an application relationship

3.3.18

cyclic

events which repeat in a regular and repetitive manner

3.3.19

data

generic term used to refer to any information carried over a fieldbus

3.3.20

data consistency

means for coherent transmission and access of the input- or output-data object between and within client and server

3.3.21

data type

relation between values and encoding for data of that type

3.3.22

data type object

entry in the object dictionary indicating a data type

3.3.23

default gateway

device with at least two interfaces in two different IP subnets acting as router for a subnet

3.3.24**device**

physical entity connected to the fieldbus composed of at least one communication element (the network element) and which may have a control element and/or a final element (transducer, actuator, etc.)

3.3.25**device profile**

collection of device dependent information and functionality providing consistency between similar devices of the same device type

3.3.26**diagnosis information**

all data available at the server for maintenance purposes

3.3.27**distributed clocks**

method to synchronize slaves and maintain a global time base

3.3.28**error**

discrepancy between a computed, observed or measured value or condition and the specified or theoretically correct value or condition

3.3.29**error class**

general grouping for related error definitions and corresponding error codes

3.3.30**error code**

identification of a specific type of error within an error class

3.3.31**event**

instance of a change of conditions

3.3.32**fieldbus memory management unit**

function that establishes one or several correspondences between logical addresses and physical memory

3.3.33**fieldbus memory management unit entity**

single element of the fieldbus memory management unit: one correspondence between a coherent logical address space and a coherent physical memory location

3.3.34**frame**

denigrated synonym for DLPDU

3.3.35**full slave**

slave device that supports both physical and logical addressing of data

3.3.36**index**

address of an object within an application process

**3.3.37
interface**

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

**3.3.38
little endian**

data representation of multi-octet fields where the least significant octet is transmitted first.

**3.3.39
master**

device that controls the data transfer on the network and initiates the media access of the slaves by sending messages and that constitutes the interface to the control system

**3.3.40
mapping**

correspondence between two objects in that way that one object is part of the other object

**3.3.41
mapping parameters**

set of values defining the correspondence between application objects and process data objects

**3.3.42
medium**

cable, optical fibre or other means by which communication signals are transmitted between two or more points

Note 1 to entry: Media is the plural of medium.

**3.3.43
message**

ordered series of octets intended to convey information

Note 1 to entry: Normally used to convey information between peers at the application layer.

**3.3.44
network**

set of nodes connected by some type of communication medium, including any intervening repeaters, bridges, routers and lower-layer gateways

**3.3.45
node**

- a) single DL-entity as it appears on one local link
- b) end-point of a link in a network or a point at which two or more links meet

[SOURCE: IEC 61158-2, for option b), with some wording adjustment]

**3.3.46
object**

abstract representation of a particular component within a device

Note 1 to entry: An object can be

- a) an abstract representation of the capabilities of a device. Objects can be composed of any or all of the following components:
 - 1) data (information which changes with time),
 - 2) configuration (parameters for behavior),
 - 3) methods (things that can be done using data and configuration);

- b) a collection of related data (in the form of variables) and methods (procedures) for operating on that data that have clearly defined interface and behavior.

3.3.47**object dictionary**

data structure addressed by Index and Sub-index that contains description of data type objects, communication objects and application objects

3.3.48**process data**

collection of application objects designated to be transferred cyclically or acyclically for the purpose of measurement and control

3.3.49**process data object**

structure described by mapping parameters containing one or several process data entities

3.3.50**producer**

node or source sending data to one or many consumers

3.3.51**resource**

processing or information capability

3.3.52**segment**

collection of one real master with one or more slaves

3.3.53**server**

object which provides services to another (client) object

3.3.54**service**

operation or function than an object and/or object class performs upon request from another object and/or object class

3.3.55**slave**

DL-entity accessing the medium only after being initiated by the preceding slave or the master

3.3.56**subindex**

sub-address of an object within the object dictionary

3.3.57**sync manager**

collection of control elements to coordinate access to concurrently used objects

3.3.58**sync manager channel**

single control elements to coordinate access to concurrently used objects

3.3.59**switch**

MAC bridge as defined in IEEE 802.1D

3.4 Common symbols and abbreviations

AL-	Application layer (as a prefix)
ALE	AL-entity (the local active instance of the application layer)
AL	AL-layer
APDU	AL-protocol-data-unit
ALM	AL-management
ALME	AL-management Entity (the local active instance of AL-management)
ALMS	AL-management service
ALS	AL-service
ALSDU	AL-service-data-unit
DL	Data-link-layer
FIFO	First-in first-out (queuing method)
OSI	Open systems interconnection
PhL	Ph-layer
QoS	Quality of service

3.5 Additional symbols and abbreviations

AoE	Automation Device Specification (ADS) over Type 12
ASE	Application service element
AR	Application relationship
CAN	Controller Area Network
CiA	CAN in Automation
CoE	CAN application protocol over Type 12 services
CSMA/CD	Carrier sense multiple access with collision detection
DC	Distributed clocks
DNS	Domain name system (server for name resolution in IP networks)
E ² PROM	Electrically erasable programmable read only memory
EoE	Ethernet tunneled over Type 12 services
ESC	Type 12 slave controller
FCS	Frame check sequence
FMMU	Fieldbus memory management unit
FoE	File access with Type 12 services
HDR	Header
ID	Identifier
IETF	Internet engineering task force
IP	Internet protocol
LAN	Local area network
MAC	Medium access control
OD	Object dictionary
PDI	Physical device internal interface (a set of elements that allows access to DL services from the AL)
PDO	Process data object
RAM	Random access memory
Rx	Receive
SDO	Service data object
SII	slave information interface
SM	Synchronization manager
SoE	Servo drive profile with Type 12 services
SyncM	Synchronization manager
TCP	Transmission control protocol
Tx	Transmit
UDP	User datagram protocol (IETF RFC 768)
VoE	Profile specific services
WKC	Working counter

3.6 Conventions

3.6.1 General concept

The services are specified in IEC 61158-5-12. The service specification defines the services that are provided by the Type 12 DL. The mapping of these services to ISO/IEC/IEEE 8802-3 is described in this document.

This document uses the descriptive conventions given in ISO/IEC 10731.

3.6.2 Convention for the encoding of reserved bits and octets

The term "reserved" may be used to describe bits in octets or whole octets. All bits or octets that are reserved should be set to zero at the sending side and shall not be tested at the receiving side except it is explicitly stated or if the reserved bits or octets are checked by a state machine.

The term "reserved" may also be used to indicate that certain values within the range of a parameter are reserved for future extensions. In this case the reserved values should not be used at the sending side and shall not be tested at the receiving side except it is explicitly stated or if the reserved values are checked by a state machine.

3.6.3 Conventions for the common codings of specific field octets

APDUs may contain specific fields that carry information in a primitive and condensed way. These fields shall be coded in the order according to Figure 1.

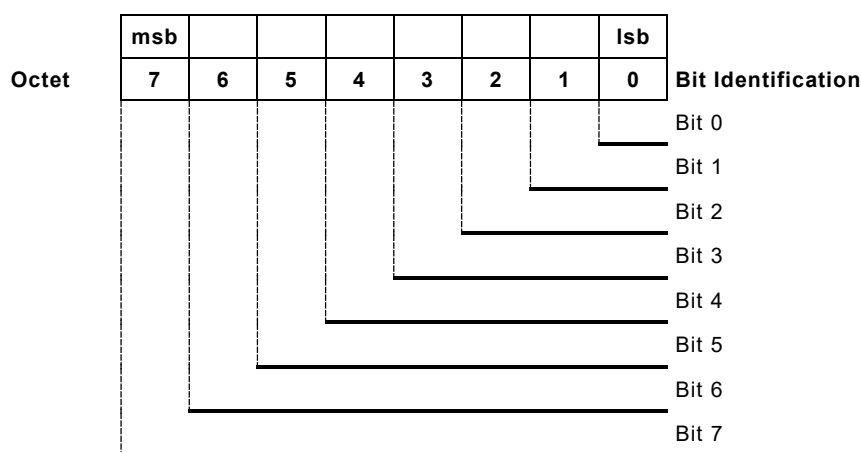


Figure 1 – Common structure of specific fields

Bits may be grouped as group of bits. Each bit or group of bits shall be addressed by its Bit Identification (e.g. Bit 0, Bit 1 to 4). The position within the octet shall be according to the figure above. Alias names may be used for each bit or group of bits or they may be marked as reserved. The grouping of individual bits shall be in ascending order without gaps. The values for a group of bits may be represented as binary, decimal or hexadecimal values. This value shall only be valid for the grouped bits and can only represent the whole octet if all 8 bits are grouped. Decimal or hexadecimal values shall be transferred in binary values so that the bit with the highest number of the group represents the msb concerning the grouped bits.

EXAMPLE Description and relation for the specific field octet

Bit 0: reserved.

Bit 1-3: Reason_Code The decimal value 2 for the Reason_Code means general error.

Bit 4-7: shall always set to one.

The octet that is constructed according to the description above looks as follows:

(msb) Bit 7 = 1,

Bit 6 = 1,

Bit 5 = 1,

Bit 4 = 1,

Bit 3 = 0,

Bit 2 = 1,

Bit 1 = 0,

(lsb) Bit 0 = 0.

This bit combination has an octet value representation of 0xf4.

3.6.4 Abstract syntax conventions

The AL syntax elements related to PDU structure are described as shown in the example of Table 1.

Frame part denotes the element that will be replaced by this reproduction.

Data field is the name of the elements.

Data Type denotes the type of the terminal symbol.

Value/Description contains the constant value or the meaning of the parameter.

Table 1 – PDU element description example

Frame part	Data Field	Data Type	Value/Description
CoE Header	Number	Unsigned9	0x00
	Reserved	Unsigned3	0x00
	Service	Unsigned4	0x02: SDO Request
SDO	Size Indicator	Unsigned1	0x00: size of Data (1..4) unspecified 0x01: size of Data in Data Set Size specified
	Transfer Type	Unsigned1	0x01: Expedited transfer
	Data Set Size	Unsigned2	0x00: 4 Octet Data 0x01: 3 Octet Data 0x02: 2 Octet Data 0x03: 1 Octet Data
	Complete Access	Unsigned1	0x00
	Command Specifier	Unsigned3	0x01: Initiate Download Request

The informational attribute types are described in C language notations (see ISO/IEC 9899) as shown in Figure 2. BYTE and WORD are elements of type unsigned char and unsigned short.

```
typedef struct
{
    Unsigned8      Type;
    Unsigned8      Revision;
    Unsigned16     Build;
    Unsigned8      NoOfSuppFmmuChannels;
    Unsigned8      NoOfSuppSyncManChannels;
    Unsigned8      RamSize;
    Unsigned8      Reserved1;
    unsigned       FmmuBitOperationNotSupp: 1;
    unsigned       Reserved2: 7;
    unsigned       Reserved3: 8;
} TDLINFORMATION;
```

Figure 2 – Type description example

The attributes of an object are described in a form as shown in Table 2.

Subindex describes a single element of the object.

Description denotes a name string for this attribute.

Data Type denotes the type of this element.

M/O/C indicates whether the attribute is mandatory (M), optional (O) or depends upon setting of other attributes (C).

Access type shows the access right to this element. R means read access right, W means write access right. It can be extended showing the AL state where the access right applies.

PDO Mapping denotes the possibility to map this attribute to TxPDO or RxPDO or to indicate that this parameter is not mappable.

Value contains the constant value and/or the meaning of the parameter.

Table 2 – Example attribute description

Sub-Index	Description	Data type	M/O/C	Access	PDO Mapping	Value
0	Number of entries	UNSIGNED8	M	R	No	4
1	Vendor ID	UNSIGNED32	M	R	No	Assigned uniquely by ETG
2	Product Code	UNSIGNED32	M	R	No	Assigned uniquely by Vendor
3	Revision Number	UNSIGNED32	M	R	No	Assigned uniquely by Vendor
4	Serial Number	UNSIGNED32	M	R	No	assigned uniquely for this device by Vendor

3.6.5 State machine conventions

The protocol sequences are described by means of State Machines.

In state diagrams states are represented as boxes and state transitions are shown as arrows. Names of states and transitions of the state diagram correspond to the names in the textual listing of the state transitions.

The textual listing of the state transitions is structured as follows, see also Table 3.

- The first column contains the name of the transition.
- The second column defines the current state.
- The third column contains an optional event followed by Conditions starting with a “/” as first line character and finally followed by the Actions starting with a “=>” as first line character.
- The last column contains the next state.

If the event occurs and the conditions are fulfilled the transition fires, i.e. the actions are executed and the next state is entered.

The layout of a Machine description is shown in Table 3. The meaning of the elements of a State Machine Description is shown in Table 4.

Table 3 – State machine description elements

#	Current state	Event /Condition => Action	Next state

Table 4 – Description of state machine elements

Description element	Meaning
Current state	name of the given states.
Next state	
#	name or number of the state transition.
Event	name or description of the event.
/Condition	boolean expression. The preceding “\” is not part of the condition.
=> Action	list of assignments and service or function invocations. The preceding “=>” is not part of the action.

The conventions used in the state machines are shown in Table 5.

Table 5 – Conventions used in state machines

Convention	Meaning
=	value of an item on the left is replaced by value of an item on the right. If an item on the right is a parameter, it comes from the primitive shown as an input event.
axx	a parameter name if a is a letter. EXAMPLE Identifier = reason means value of a 'reason' parameter is assigned to a parameter called 'Identifier.'
"xxx"	indicates fixed visible string. EXAMPLE Identifier = "abc" means value "abc" is assigned to a parameter named 'Identifier.'
nnn	if all elements are digits, the item represents a numerical constant shown in decimal representation.
0xnn	if all elements nn are digits, the item represents a numerical constant shown in hexadecimal representation.
==	a logical condition to indicate an item on the left is equal to an item on the right.
<	a logical condition to indicate an item on the left is less than the item on the right.
>	a logical condition to indicate an item on the left is greater than the item on the right.
!=	a logical condition to indicate an item on the left is not equal to an item on the right.
&&	logical "AND"
	logical "OR"
!	logical "NOT"
+ – * /	arithmetic operators
;	separator of expressions

Readers are strongly recommended to refer to the subclauses for the attribute definitions, the local functions and the FDL-PDU definitions to understand protocol machines. It is assumed that readers have sufficient knowledge of these definitions and they are used without further explanations.

Further constructs as defined in C language notation (see ISO/IEC 9899) can be used to describe conditions and actions.

4 Application layer protocol specification

4.1 Operating principle

Type 12 is a Real Time Ethernet technology that aims to maximize the utilization of the full duplex Ethernet bandwidth. Medium access control employs the master/slave principle, where the master node (typically the control system) sends the Ethernet frames to the slave nodes, which extract data from and insert data into these frames.

From an Ethernet point of view, a Type 12 segment is a single Ethernet device, which receives and sends ISO/IEC/IEEE 8802-3 Ethernet frames. However, this Ethernet device is not limited to a single Ethernet controller with a downstream microprocessor, but may consist of a large number of slave devices. These process the incoming frames directly and extract the relevant user data or insert data and transfer the frame to the next slave device. The last slave device within the segment sends the fully processed frame back, so that it is returned by the first slave device to the master as response frame.

This procedure utilizes the full duplex mode of Ethernet: both communication directions are operated independently. Direct communication without a switch between a master device and a Type 12 segment consisting of one or several slave devices may be established.

Industrial communication systems have to meet different requirements in terms of the data transmission characteristics. Parameter data is transferred acyclically and in large quantities, whereby the timing requirements are relatively non-critical, and the transmission is usually triggered by the control system. Diagnostic data is also transferred acyclically and event-driven, but the timing requirements are more demanding, and the transmission is usually triggered by a peripheral device.

Process data, on the other hand, is typically transferred cyclically with different cycle times. The timing requirements are most stringent for process data communication. Type 12 supports a variety of services and protocols to meet these differing requirements.

4.2 Node reference model

4.2.1 Mapping onto OSI basic reference model

Type 12 is described using the principles, methodology and model of ISO/IEC 7498-1. The OSI model provides a layered approach to communications standards, whereby the layers can be developed and modified independently. The Type 12 specification defines functionality from top to bottom of a full OSI stack, and some functions for the users of the stack. Functions of the intermediate OSI layers, layers 3 – 6, are consolidated into either the Type 12 Data Link layer or the Type 12 Application layer. Likewise, features common to users of the Fieldbus Application Layer may be provided by the Type 12 Application layer to simplify user operation, as noted in Figure 3.

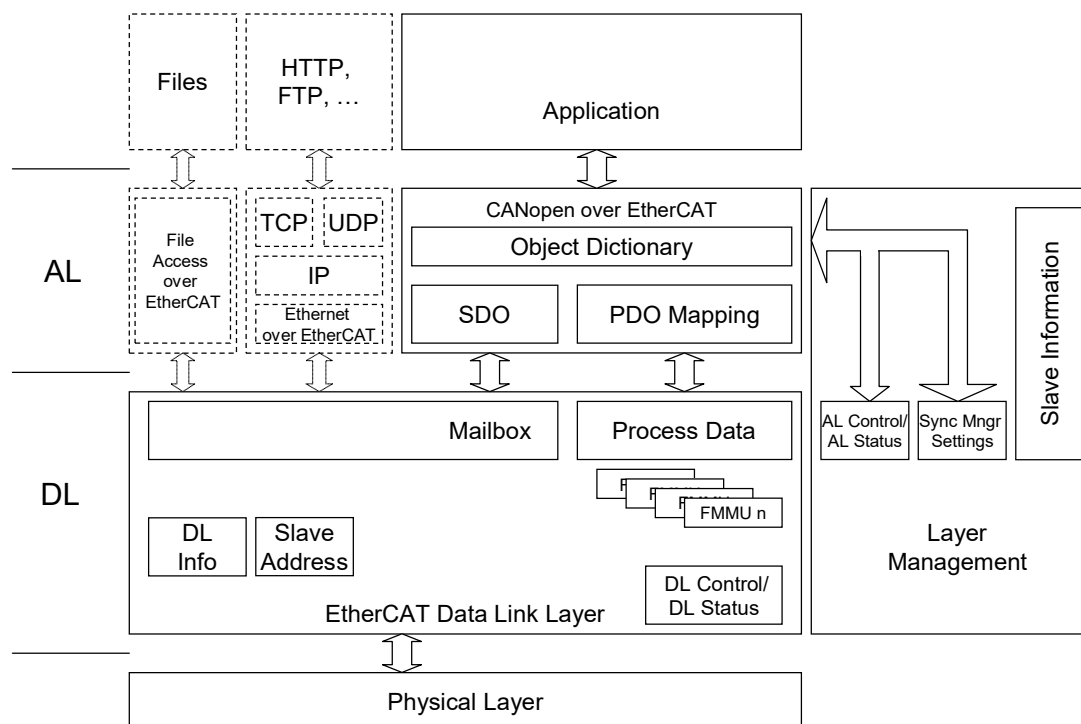


Figure 3 – Slave Node Reference Model

4.2.2 Data Link Layer features

The data link layer provides basic time critical support for data communications among devices. The term “time-critical” is used to describe applications having a time-window, within which one or more specified actions are required to be completed with some defined level of certainty. Failure to complete specified actions within the time window risks failure of the applications requesting the actions, with attendant risk to equipment, plant and possibly human life.

The data link layer has the task to compute, compare and generate the frame check sequence and provide communications by extracting data from and/or including data into the Ethernet frame. This is done depending on the data link layer parameters which are stored at pre-defined memory locations. The application data is made available to the application layer in physical memory, either in a mailbox configuration or within the process data section.

Additionally, some data structures in the Data Link layer will be used to allow a coordination of the interaction between master and slave such as AL Control, Status and Event and Sync manager settings.

4.2.3 Application Layer structure

The Application Layer consists of the following elements.

- A real time entity (mandatory)
- An entity that deals with TCP/UDP/IP and related protocols (optional)
- A file access utility (optional)
- A Management unit (mandatory)

The Application Layer uses the services provided by the Type 12 Data Link Layer to convey the Application Layer service data.

5 FAL syntax description

5.1 Coding principles

Application layer uses DL objects as defined in IEC 61158-4-12.

5.2 Data types and encoding rules

5.2.1 General description of data types and encoding rules

The format of this data and its meaning have to be known by the producer and consumer(s) to be able to exchange meaningful data. This specification models this by the concept of data types.

The encoding rules define the representation of values of data types and the transfer syntax for the representations. Values are represented as bit sequences. Bit sequences are transferred in sequences of octets (bytes). For numerical data types the encoding is little endian style as shown in Table 6.

The data types and encoding rules shall be valid for the DL services and protocols as well as for the AL services and protocols specified. The encoding rules for the Ethernet frame are specified in ISO/IEC/IEEE 8802-3. The DLSDU of Ethernet is an octet string. The transmission order within octets depends upon MAC and PhL encoding rules.

5.2.2 Encoding of a Boolean value

- The encoding of a Boolean value shall be primitive. The ContentsOctets shall consist of a single octet.
- If the Boolean value is FALSE, the ContentsOctets shall be 0 (zero). If the Boolean value is TRUE, the ContentsOctets shall be 0xff.

5.2.3 Encoding of a Time Of Day with and without date indication value

- The encoding of a Time Of Day with and without date indication value shall be primitive.
- The ContentsOctets shall be equal in value to the octets in the data value, as shown in Figure 4.

bits	7	6	5	4	3	2	1	0	
octets									
1	0	0	0	0	2^{27}	2^{26}	2^{25}	2^{24}	number of
2	2^{23}	2^{22}	2^{21}	2^{20}	2^{19}	2^{18}	2^{17}	2^{16}	milliseconds
3	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	since
4	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	midnight
5	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	number of
6	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	days since 1984-01-01
									only with date indication
msb									

Figure 4 – Encoding of Time of Day value

5.2.4 Encoding of a Time Difference with and without date indication value

- The encoding of a Time Difference with and without date indication value shall be primitive.
- The ContentsOctets shall be equal in value to the octets in the data value, as shown in Figure 5.

bits	7	6	5	4	3	2	1	0	
octets									milliseconds
1	2 ³¹	2 ³⁰	2 ²⁹	2 ²⁸	2 ²⁷	2 ²⁶	2 ²⁵	2 ²⁴	
2	2 ²³	2 ²²	2 ²¹	2 ²⁰	2 ¹⁹	2 ¹⁸	2 ¹⁷	2 ¹⁶	
3	2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	
4	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	days
5	2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	
6	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	
msb									

Figure 5 – Encoding of Time Difference value

5.2.5 Transfer syntax for bit sequences

For transmission a bit sequence is reordered into a sequence of octets. Hexadecimal notation is used for octets as specified in ISO/IEC 9899. Let $b = b_0 \dots b_{n-1}$ be a bit sequence. Denote k a non-negative integer such that $8(k-1) < n \leq 8k$. Then b is transferred in k octets assembled as shown in Table 6. The bits b_i , $i \geq n$ of the highest numbered octet are do not care bits.

Octet 1 is transmitted first and octet k is transmitted last. Hence the bit sequence is transferred as follows across the network (transmission order within an octet is determined by ISO/IEC/IEEE 8802-3):

$$b_7, b_6, \dots, b_0, b_{15}, \dots, b_8, \dots$$

Table 6 – Transfer Syntax for bit sequences

octet number	1.	2.	k.
	$b_7 \dots b_0$	$b_{15} \dots b_8$	$b_{8k-1} \dots b_{8k-8}$

EXAMPLE

Bit 9	...	Bit 0
10b	0001b	1100b
0x2	0x1	0xC
= 0x21C		

The bit sequence $b = b_0 \dots b_9 = 0011\ 1000\ 01_b$ represents an Unsigned10 with the value 0x21C and is transferred in two octets: first 0x1C and then 0x02.

5.2.6 Encoding of a Unsigned Integer value

Data of basic data type Unsigned n has values in the non-negative integers. The value range is 0, ..., 2^n-1 . The data is represented as bit sequences of length n . The bit sequence

$$b = b_0 \dots b_{n-1}$$

is assigned the value

$$\text{Unsignedn}(b) = b_{n-1} \times 2^{n-1} + \dots + b_1 \times 2^1 + b_0 \times 2^0$$

The bit sequence starts on the left with the least significant byte (Octet).

EXAMPLE The value 266 = 0x10A with data type Unsigned16 is transferred in two octets, first 0x0A and then 0x01.

The Unsignedn data types are transferred as specified in Table 7. Unsigned data types as Unsigned1 to Unsigned7 and Unsigned 9 to Unsigned15 will be used too. In this case the next element will start at the first free bit position as denoted in 3.6.3.

Table 7 – Transfer syntax for data type Unsignedn

octet number	1.	2.	3.	4.	5.	6.	7.	8.
Unsigned8	$b_7..b_0$							
Unsigned16	$b_7..b_0$	$b_{15}..b_8$						
Unsigned32	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$				
Unsigned64	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$	$b_{39}..b_{32}$	$b_{47}..b_{40}$	$b_{55}..b_{48}$	$b_{63}..b_{56}$

BYTE is used as UNSIGNED8, WORD is used as UNSIGNED16.

5.2.7 Encoding of a Signed Integer value

Data of basic data type Integern has values in the integers. The value range is from -2^{n-1} to $2^{n-1}-1$. The data is represented as bit sequences of length n . The bit sequence

$$b = b_0 \dots b_{n-1}$$

is assigned the value

$$\text{Integern}(b) = b_{n-2} \times 2^{n-2} + \dots + b_1 \times 2^1 + b_0 \times 2^0 \quad \text{if } b_{n-1} = 0$$

and, performing two's complement arithmetic,

$$\text{Integern}(b) = -\text{Integern}(\text{^}b) - 1 \quad \text{if } b_{n-1} = 1$$

NOTE The bit sequence starts on the left with the least significant bit.

EXAMPLE The value -266 = 0xFE6 with data type Integer16 is transferred in two octets, first 0xF6 and then 0xFE.

The Integern data types are transferred as specified in Table 8. Integer data types as Integer1 to Integer7 and Integer9 to Integer15 will be used too. In this case the next element will start at the first free bit position as denoted in 3.6.3.

Table 8 – Transfer syntax for data type Integer

octet number	1.	2.	3.	4.	5.	6.	7.	8.
Integer8	$b_7..b_0$							
Integer16	$b_7..b_0$	$b_{15}..b_8$						
Integer32	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$				
Integer64	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$	$b_{39}..b_{32}$	$b_{47}..b_{40}$	$b_{55}..b_{48}$	$b_{63}..b_{56}$

5.2.8 Encoding of a Floating Point value

Float32::= OCTET STRING SIZE (4) -- ISO/IEC/IEEE 60559 Single precision

Float64::= OCTET STRING SIZE (8) -- ISO/IEC/IEEE 60559 Double precision

5.2.9 Encoding of a Visible String value

- The encoding of a variable length VisibleString value shall be primitive.
- There is no Length field and no termination symbol; the length is encoded implicitly.
- The ContentsOctets shall be a sequence of octets. The leftmost string element is encoded in the first octet, followed by the second octet, followed by each octet in turn up to and including the last octet as rightmost of the ContentsOctets.

5.2.10 Encoding of a Unicode String value

- The encoding of a variable length UnicodeString value shall be primitive.
- There is no Length field; the length is encoded implicitly.
- The ContentsOctets shall be a sequence of unsigned integer. The leftmost string element is encoded in the first unsigned integer, followed by the second unsigned integer, followed by each unsigned integer in turn up to and including the last unsigned integer as rightmost of the ContentsOctets.

5.2.11 Encoding of an Octet String value

- The encoding of a variable length OctetString value shall be primitive.
- There is no Length field; the length is encoded implicitly.
- The ContentsOctets shall be a sequence of octets. The leftmost string element is encoded in the first octet, followed by second octet, followed by each octet in turn up to and including the last octet as rightmost of the ContentsOctets.

5.2.12 Encoding of GUID

Data of basic data type GUID (Globally Unique Identifier) is a unique reference number used as an identifier. The value of a GUID is stored as a 128-bit integer.

5.3 AR coding**5.3.1 AL Control Request (Indication)**

The attribute types of AL Control Request are described in Figure 6.

```
typedef struct
{
    unsigned    State:          4;
    unsigned    Acknowledge:    1;
    unsigned    IdRequest:      1;
    unsigned    Reserved:       2;
    unsigned    ApplSpecific:    8;
} TALCONTROL;
```

Figure 6 – AL Control Request structure

The AL Control Request is mapped to a DL write service to the DL-user control register object R1 and R2 as specified in IEC 61158-4-12. The AL Control Request coding is specified in Table 9.

Table 9 – AL Control Description

Parameter	DL-user Register	Data Type	Value
State	R1	Unsigned4	1: Init 2: Pre-Operational 3: Bootstrap 4: Safe-Operational 8: Operational
Acknowledge	R1	Unsigned1	0: Parameter Change of the AL Status Register will be unchanged 1: Parameter Change of the AL Status Register will be reset
IdRequest	R1	Unsigned1	0: ID is not requested 1: Request of ID
Reserved	R1	Unsigned2	shall be zero
Reserved	R2	Unsigned8	

5.3.2 AL Control Response (Confirmation)

The AL Control Response is mapped to a DL read service to the DL-user status register object and register R4, R5 and R6 as specified in IEC 61158-4-12. The attribute types of AL Control Response are described in Figure 7.

```
typedef struct
{
    unsigned    State:          4;
    unsigned    Change:         1;
    unsigned    IdLoaded:       1;
    unsigned    Reserved1:      2;
    unsigned    ApplSpecific:    8;
    unsigned    Reserved2:      16;
    unsigned    AlStatusCode:    16;
} TALSTATUS;
```

Figure 7 – AL Control Response structure

The AL Control Response coding is specified in Table 10.

Table 10 – AL Control Response

Parameter	DL-user Register	Data Type	Value
State	R3	Unsigned4	1: Init 2: Pre-Operational 3: Bootstrap 4: Safe-Operational 8: Operational
Change	R3	Unsigned1	0: State transition successful 1: State transition not successful
IdLoaded	R3	Unsigned1	0: Value in R6 does not represent ID 1: Value in R6 represents ID
Reserved	R3	Unsigned2	shall be zero
Reserved	R4	Unsigned8	
Reserved	R5	Unsigned16	
AL Status Code	R6	Unsigned16	see Table 11

Table 11 – AL Status Codes

Code	Description	Current state (or state change)	Resulting state
0x0000	No error	Any	Current state
0x0001	Unspecified error	Any	I + E, P + E, S + E
0x0002	No Memory	Any	I + E, P + E, S + E
0x0003	Invalid Device Setup	P -> S	P + E
0x0005	Reserved due to compatibility reasons		
0x0011	Invalid requested state change	I -> S, I -> O, P -> O O -> B, S -> B, P -> B	I + E, P + E, S + E
0x0012	Unknown requested state	Any	I + E, P + E, S + E
0x0013	Bootstrap not supported	I -> B	I + E
0x0014	No valid firmware	I -> P	I + E
0x0015	Invalid mailbox configuration	I -> B	I + E
0x0016	Invalid mailbox configuration	I -> P	I + E
0x0017	Invalid sync manager configuration	P -> S, S -> O	Current state + E
0x0018	No valid inputs available	O, S -> O	S + E
0x0019	No valid outputs	S, O, S -> O	S + E
0x001A	Synchronization error	O, S -> O	S + E
0x001B	Sync manager watchdog	O, S	S + E
0x001C	Invalid Sync Manager Types	O, S, P -> S	S + E
0x001D	Invalid Output Configuration	O, S, P -> S	P + E
0x001E	Invalid Input Configuration	O, S, P -> S	P + E
0x001F	Invalid Watchdog Configuration	O, S, P -> S	P + E
0x0020	Slave needs cold start	Any	I + E, P + E, S + E
0x0021	Slave needs INIT	B, P, S, O	I + E, P + E, S + E

Code	Description	Current state (or state change)	Resulting state
0x0022	Slave needs PREOP	S, O	S + E, O + E
0x0023	Slave needs SAFEOP	O	O + E
0x0024	Invalid Input Mapping	P -> S	P + E
0x0025	Invalid Output Mapping	P -> S	P + E
0x0026	Inconsistent Settings	P -> S	P + E
0x0027	FreeRun not supported	P -> S	P + E
0x0028	SyncMode not supported	P -> S	P + E
0x0029	FreeRun needs 3Buffer Mode	P -> S	P + E
0x002A	Background Watchdog	S, O	P + E
0x002B	No Valid Inputs and Outputs	O, S -> O	S + E
0x002C	Fatal Sync Error	O	S + E
0x002D	No Sync Error	O, S, P -> S	S + E
0x0030	Invalid DC SYNC Configuration	O, S -> O, P -> S	P + E, S + E
0x0031	Invalid DC Latch Configuration	O, S -> O, P -> S	P + E, S + E
0x0032	PLL Error	O, S -> O	S + E
0x0033	DC Sync IO Error	O, S -> O	S + E
0x0034	DC Sync Timeout Error	O, S -> O	S + E
0x0035	DC Invalid Sync Cycle Time	P -> S	P + E
0x0036	DC Sync0 Cycle Time	P -> S	P + E
0x0037	DC Sync1 Cycle Time	P -> S	P + E
0x0041	MBX_AOE	B, P, S, O	I + E, P + E, S + E
0x0042	MBX_EOE	B, P, S, O	I + E, P + E, S + E
0x0043	MBX_COE	B, P, S, O	I + E, P + E, S + E
0x0044	MBX_FOE	B, P, S, O	I + E, P + E, S + E
0x0045	MBX_SOE	B, P, S, O	I + E, P + E, S + E
0x004F	MBX_VOE	B, P, S, O	I + E, P + E, S + E
0x0050	EEPROM no access	Any	I + E, P + E, S + E
0x0051	EEPROM Error	Any	I + E, P + E, S + E
0x0060	Slave restarted locally	Any	I
0x0061	Device Identification value updated	P	P + E
0x0062 ...0 x00EF	Reserved		
0x00F0	Application controller available	I	I + E
other codes < 0x8000	reserved		
0x8000 – 0xFFFF	Vendor specific		

5.3.3 AL State Changed

The AL State Changed is mapped to a DL read service to the AL Status and AL Status Code object. The attribute types of AL State Changed are described in Figure 8.

```
typedef struct
{
    unsigned    State:          4;
    unsigned    Change:         1;
    unsigned    Reserved1:      3;
    unsigned    ApplSpecific:   8;
    unsigned    Reserved2:     16;
    unsigned    AlStatusCode:   16;
} TALSTATUS;
```

Figure 8 – AL State Changed structure

The AL State Changed coding is specified in Table 12.

Table 12 – AL State Changed

Parameter	DL-user Register	Data Type	Value
State	R3	Unsigned4	1: Init 2: Pre-Operational 3: Bootstrap 4: Safe-Operational 8: Operational
Change	R3	Unsigned1	shall be one
Reserved	R3	Unsigned3	shall be zero
Application Specific	R4	Unsigned8	application specific
Reserved	R5	Unsigned16	shall be zero
AL Status Code	R6	Unsigned16	see Table 11

5.3.4 AL AR Attributes

AL AR attributes can be accessed by DL read or write services or by local read write services.

The attribute types of PDI Control are described in Figure 9.

```
typedef struct
{
    unsigned    PDType:          8;
    unsigned    StrictALControl:  1;
    unsigned    Reserved:        7;
} TPDICONTROL;
```

Figure 9 – PDI Control type description

The PDI Control coding is specified in Table 13. PDI Control will be loaded from SII at start-up.

Table 13 – PDI Control

Parameter	DL-user Register	Data Type	Access DL	Access local	Value/Description
PDI Type	R7	Unsigned8	R	R	type specific (see IEC 61158-3-12 DL information parameter)
Strict AL Control	Copy	Unsigned1	R	R	0x00: AL Management will be done by an application Controller 0x01: AL Management will be emulated (AL status follows directly AL control)

The PDI Configuration coding is controller specific as shown in Table 14 and set by SII at start-up.

Table 14 – PDI Configuration

Parameter	DL-user Register	Data Type	Access DL	Access local	Value/Description
Application Specific	R8	unsigned8	R	R	applicatgion specific

The attribute types of Sync Configuration are described in Figure 10.

```
typedef struct
{
    unsigned    SignalCondSync0:      2;
    unsigned    EnableSignalSync0:    1;
    unsigned    EnableInterruptSync0: 1;
    unsigned    SignalCondSync1:      2;
    unsigned    EnableSignalSync1:    1;
    unsigned    EnableInterruptSync1: 1;
} TSYNCCFG;
```

Figure 10 – Sync Configuration type description

The Sync Configuration coding is specified in Table 15. Sync Configuration will be loaded from SII at start-up.

Table 15 – Sync Configuration

Parameter	DL-user register	Data Type	Access DL	Access local	Value/Description
Signal Conditioning Sync0	R8	unsigned2	R	R	controller specific
Enable Signal Sync0	R8	unsigned1	R	R	0x00: disable 0x01: enable
Enable Interrupt Sync0	R8	unsigned1	R	R	0x00: disable 0x01: enable
Signal Conditioning Sync1	R8	unsigned2	R	R	controller specific
Enable Signal Sync1	R8	unsigned1	R	R	0x00: disable 0x01: enable
Enable Interrupt Sync1	R8	unsigned1	R	R	0x00: disable 0x01: enable

5.4 SII coding

The Slave Information Interface Area coding is specified in Table 16 and Table 17. Address means a word address (e.g. 0 is first word, 1 is second word).

Table 16 – Slave Information Interface Area

Parameter	Address	Data Type	Value/Description
PDI Control	0x0000	Unsigned16	initialization value for PDI Control register (0x140-0x141)
PDI Configuration	0x0001	Unsigned16	initialization value for PDI Configuration register (0x150-0x151)
SyncImpulseLen	0x0002	Unsigned16	sync Impulse in multiples of 10 ns
PDI Configuration2	0x0003	Unsigned16	initialization value for PDI Configuration register R8 most significant word (0x152-0x153)
Configured Station Alias	0x0004	Unsigned16	alias Address
Reserved	0x0005	BYTE[4]	Reserved for future use
Checksum	0x0007	Unsigned16	low byte contains remainder of division of word 0 to word 6 as unsigned number divided by the polynomial x^8+x^2+x+1 (initial value 0xFF)
Vendor ID	0x0008	Unsigned32	CAN-Object 0x1018, Subindex 1
Product Code	0x000A	Unsigned32	CAN-Object 0x1018, Subindex 2
Revision Number	0x000C	Unsigned32	CAN-Object 0x1018, Subindex 3
Serial Number	0x000E	Unsigned32	CAN-Object 0x1018, Subindex 4
Reserved	0x0010	BYTE[8]	Reserved for future use
Bootstrap Receive Mailbox Offset	0x0014	Unsigned16	receive Mailbox Offset for Bootstrap state (master to slave)
Bootstrap Receive Mailbox Size	0x0015	Unsigned16	receive Mailbox Size for Bootstrap state (master to slave) Standard Mailbox size and Bootstrap Mailbox can differ. A bigger Mailbox size in Bootstrap mode can be used for optimization
Bootstrap Send Mailbox Offset	0x0016	Unsigned16	send Mailbox Offset for Bootstrap state (slave to master)
Bootstrap Send Mailbox Size	0x0017	Unsigned16	send Mailbox Size for Bootstrap state (slave to master) Standard Mailbox size and Bootstrap Mailbox can differ. A bigger Mailbox size in Bootstrap mode can be used for optimization
Standard Receive Mailbox Offset	0x0018	Unsigned16	receive Mailbox Offset for Standard state (master to slave)
Standard Receive Mailbox Size	0x0019	Unsigned16	receive Mailbox Size for Standard state (master to slave)
Standard Send Mailbox Offset	0x001A	Unsigned16	send Mailbox Offset for Standard state (slave to master)
Standard Send Mailbox Size	0x001B	Unsigned16	send Mailbox Size for Standard state (slave to master)
Mailbox Protocol	0x001C	Unsigned16	mailbox Protocols Supported as defined in Table 18
Reserved	0x001D	BYTE[66]	Reserved for future use
Size	0x003E	Unsigned16	size of E2PROM in [KiBit] + 1 NOTE KiBit means 1024 Bit. NOTE size = 0 means a EEPROM size of 1 KiBit
Version	0x003F	Unsigned16	this Version is 1

Table 17 – Slave Information Interface Categories

Parameter	Address	Data Type	Value/Description
First Category Header	0x0040	Unsigned15	category Type as defined in Table 19
	0x0040	Unsigned1	vendor Specific
	0x0041	Unsigned16	following Category Word Size x
First Category Data	0x0042	Category dependent	category Data
Second Category Header	0x0042 + x	Unsigned15	category Type as defined in Table 19
	0x0042 + x	Unsigned1	vendor Specific
	0x0043 + x	Unsigned16	following Category Word Size
Second Category Data	0x0044 + x	Category dependent	category Data
...			continuation of the scheme until last category

Table 18 – Mailbox Protocols Supported Types

Protocol	Value	Description
AoE	0x0001	ADS over Type 12 (routing and parallel services)
EoE	0x0002	Ethernet over Type 12 (tunnelling of Data Link services)
CoE	0x0004	CAN application protocol over Type 12(access to SDO)
FoE	0x0008	File Access over Type 12
SoE	0x0010	Servo Drive Profile over Type 12
VoE	0x0020	Vendor specific protocol over Type 12

Table 19 – Categories Types

Protocol	Value	Description
NOP	00	no info
Device specific	01 – 09	Device specific categories shall not be overwritten by Master or configuration tool. Might be used for calibration values)
STRINGS	10	string repository for other Categories structure of this category data see Table 20
DataTypes	20	data Types for future use
General	30	general information structure of this category data see Table 21
FMMU	40	FMMUs to be used structure of this category data see Table 23
SyncM	41	Sync Manager Configuration structure of this category data see Table 24
TXPDO	50	TxPDO description structure of this category data see Table 25
RXPDO	51	RxPDO description structure of this category data see Table 25
DC	60	Distributed Clock for future use
Reserved	60-2047	Reserved
Vendor specific	0x0800-0x0FFF	Vendor specific categories
Reserved	0x1000-0xFFFF	Reserved
End	0xffff	

Table 20 – Structure Category String

Parameter	Byte Address	Data Type	Value/Description
nStrings	0x0000	Unsigned8	number of Strings
str1_len	0x0001	Unsigned8	length String1
str_1	0x0002	BYTE [str1_len]	String1 Data
str2_len	0x0002+str1_len	Unsigned8	length String2
str_2	0x0003+str1_len	BYTE [str2_len]	String2 Data
....			
strn_len	0x000z	Unsigned8	length Stringn
str_n	0x000z+1	BYTE [strn_len]	Stringn Data
PAD_Byte	0x000y	BYTE	padding if Category length is odd

NOTE 1 String means VISIBLESTRING data type by default.

NOTE 2 The first string is referenced by 1 and following, a string index of 0 refers to an empty string.

Table 21 – Structure Category General

Parameter	Byte Address	Data Type	Value/Description
GroupIdx	0x0000	Unsigned8	Group Information (Vendor specific) – Index to STRINGS
ImgIdx	0x0001	Unsigned8	Image Name (Vendor specific) – Index to STRINGS
OrderIdx	0x0002	Unsigned8	Device Order Number (Vendor specific) – Index to STRINGS
NamIdx	0x0003	Unsigned8	Device Name Information (Vendor specific) – Index to STRINGS
Reserved	0x0004	Unsigned8	reserved
CoE Details	0x0005	Unsigned8	Bit 0: Enable SDO Bit 1: Enable SDO Info Bit 2: Enable PDO Assign Bit 3: Enable PDO Configuration Bit 4: Enable Upload at startup Bit 5: Enable SDO complete acces
FoE Details	0x0006	Unsigned8	Bit 0: Enable Foe
EoE Details	0x0007	Unsigned8	Bit 0: Enable EoE
SoEChannels	0x0008	Unsigned8	reserved
DS402Channels	0x0009	Unsigned8	reserved
SysmanClass	0x000a	Unsigned8	reserved
Flags	0x000b	Unsigned8	Bit 0: Enable SafeOp Bit 1: Enable notLRW Bit 2: MboxDataLinkLayer Bit 3,4: Selection of identification method as defined in Table 22
CurrentOnEBus	0x000c	Signed16	EBus Current Consumption in mA, negative Values means feeding in current
GroupIdx	0x000e	Unsigned8	Index to Strings – duplicate for compatibility reasons
Reserved	0x000f	BYTE[1]	Reserved
Physical Port	0x0010	Unsigned16	Description of Physical Ports:

Parameter	Byte Address	Data Type	Value/Description
			0x00: not use 0x01: MII 0x02: reserved 0x03: EBUS 0x04: Fast Hot Connect Each port is describe by 4 bits: 3:0: Port 0 7:4: Port 1 11:8: Port 2 15:9: Port3 NOTE Fast Hot Connect means a Port with Ethernet Physical Layer and Autonegotiation off (100Mbps full duplex)
Physical Memory Address	0x0012	Unsigned16	Element defines the ESC memory address where the Identification ID is saved if Identification Method = IdentPhyM
Reserved2	0x0014	BYTE[12]	reserved

Table 22 – Identification Methods

Parameter	Value	Description
IdentALSts	Bit3	ID selector mirrored in AL Statud Code
IdentPhyM	Bit4	ID selector value mirrored in specific physical memory as deonted by the parameter “Physical Memory Address”

Table 23 – Structure Category FMMU

Parameter	Byte Address	Data Type	Value/Description
FMMU0	0x0000	Unsigned8	0x00: FMMU0 not used 0x01: FMMU0 used for Outputs 0x02: FMMU0 used for Inputs 0x03: FMMU0 used for SyncM Status(Read Mailbox) 0xFF: FMMU0 not used
FMMU1	0x0001	Unsigned8	0x00: FMMU1 not used 0x01: FMMU1 used for Outputs 0x02: FMMU1 used for Inputs 0x03: FMMU1 used for SyncM Status(Read Mailbox) 0xFF: FMMU1 not used
	...		continued if more than 2 FMMU used

Table 24 – Structure Category SyncM for each Element

Parameter	Byte Address	Data Type	Value/Description
Physical Start Address	0x0000	WORD	origin of Data (see Physical Start Address of SyncM)
Length	0x0002	WORD	
Control Register	0x0004	Unsigned8	defines Mode of Operation (see Control Register of SyncM)
Status Register	0x0005	BYTE	don't care
Enable Synch Manager	0x0006	Unsigned8	enable SynchM Bit 0: enable Bit 1: fixed content (info for config tool –SyncMan has fixed content) Bit 2: virtual SyncManager (virtual SyncMan – no hardware resource used) Bit 3: opOnly (SyncMan should be enabled only in OP state) Bit 7:4: reserved
Sync Manager Type	0x0007	BYTE	SyncManager Type 0x00 = not used or unknown 0x01 = used for mailbox out 0x02 = used for mailbox in 0x03 = used for process data outputs 0x04 = used for process data inputs

Table 25 – Structure Category TXPDO and RXPDO for each PDO

Parameter	Address	Data Type	Value/Description
PDO Index	0x0000	Unsigned16	ror RxPDO: 0x1600 to 17FF, ror TxPDO: 0x1A00 to 1BFF
nEntry	0x0002	Unsigned8	number of Entries
SyncM	0x0003	Unsigned8	related Sync Manager
Synchronization	0x0004	Unsigned8	reference to DC Synch
Nameldx	0x0005	Unsigned8	name of the Object – Index to STRINGS
Flags	0x0006	WORD	for future use
Entry 1	0x0008	8 BYTE	repeated for each entry as defined in Table 26
...			
Entry nEntry	nEntry*8	8 BYTE	repeated for each entry as defined in Table 26

Table 26 – Structure PDO Entry

Parameter	Offset within entry structure	Data Type	Value/Description
Entry Index	0x0000	Unsigned16	index of the entry
Subindex	0x0002	Unsigned8	subindex
Entry Name Idx	0x0003	Unsigned8	name of the Entry – Index to STRINGS
Data Type	0x0004	Unsigned8	Data Type of the entry (Index in CoE Object Dictionary)
BitLen	0x0005	Unsigned8	Data Length of the entry
Flags	0x0006	WORD	for future use

5.5 Isochronous PDI coding

The attribute types of Distributed Clock sync and latch are described in Figure 11.

```
typedef struct
{
    BYTE          Reserved1;
    unsigned      CyclicOperationEnable:    1;
    unsigned      SYNC0Activate:             1;
    unsigned      SYNC1Activate:             1;
    unsigned      Reserved2:                 5;
    WORD          SYNC0Pulse;
    BYTE          Reserved5[10];
    unsigned      Interrupt1Status:          1;
    unsigned      Reserved2:                 7;
    unsigned      Interrupt2Status:          1;
    unsigned      Reserved3:                 7;
    DWORD         CyclicOperationStartTime;
    BYTE          Reserved4[12];
    DWORD         SYNC0CycleTime;
    DWORD         SYNC1CycleTime;
    unsigned      Latch0PosEdge:             1;
    unsigned      Latch0NegEdge:             1;
    unsigned      Reserved5:                 14;
    unsigned      Latch1PosEdge:             1;
    unsigned      Latch1NegEdge:             1;
    unsigned      Reserved6:                 14;
    BYTE          Reserved7[4];
    unsigned      Latch0PosEvnt:             1;
    unsigned      Latch0NegEvnt:             1;
    unsigned      Reserved8:                 6;
    unsigned      Latch1PosEvnt:             1;
    unsigned      Latch1NegEvnt:             1;
    unsigned      Reserved9:                 6;
    DWORD         Latch0PosEdgeValue;
    BYTE          Reserveda[4];
    DWORD         Latch0NegEdgeValue;
    BYTE          Reservedb[4];
    DWORD         Latch1PosEdgeValue;
    BYTE          Reservedc[4];
    DWORD         Latch1NegEdgeValue;
    BYTE          Reservedd[4];
} TDCISOCHRON;
```

Figure 11 – Distributed Clock sync and latch type description

The Distributed Clock sync parameter encoding is described in Table 27. The parameters are mapped to DL DC user parameter P1 to P6. The events SYNC0 and SYNC1 are mapped to the DL events.

Table 27 – Distributed Clock sync parameter

Parameter	DC user parameter	Data Type	Access Type Type 12 DL	Access Type PDI	Value/Description
Cyclic Operation Enable	P1	Unsigned1	RW	R	0: disabled 1: enabled
SYNC0 activate	P1	Unsigned1	RW	R	0: deactivated 1: SCNC0 pulse generated
SYNC1 activate	P1	Unsigned1	RW	R	0: deactivated 1: SCNC1 pulse generated
SYNC Pulse	P2	Unsigned16	R	R	Taken from SII
Interrupt 0 Status	P3	Unsigned1	R	R	0: not active 1: active
Reserved	P3	Unsigned7	R	R	
Interrupt 1 Status	P3	Unsigned1	R	R	0: not active 1: active
Reserved	P3	Unsigned7	R	R	
Cyclic Operation Start Time	P4	Unsigned32	RW	R	the interrupt generation will start when the lower 32 bits of the system time will reach this value (in ns)
SYNC0 Cycle Time	P5	DWORD	RW	R	cycle time of SYNC0
SYNC1 Cycle Time	P6	DWORD	RW	R	cycle time of SYNC1

The Distributed Clock latch data encoding is described in Table 28.

Table 28 – Distributed Clock latch data

Parameter	DC user parameter	Data Type	Access Type Type 12 DL	Access Type PDI	Value/Description
Latch0 positive Edge	P7	Unsigned1	RW	R	0: continuous 1: single
Latch0 negative Edge	P7	Unsigned1	RW	R	0: continuous 1: single
Reserved	P7	Unsigned6	R	R	
Latch1 positive Edge	P7	Unsigned1	RW	R	0: continuous 1: single
Latch1 negative Edge	P7	Unsigned1	RW	R	0: continuous 1: single
Reserved	P7	Unsigned6	R	R	
Latch0 positive Event	P8	Unsigned1	RW	R	0: no Event 1: Event stored
Latch0 negative Event	P8	Unsigned1	RW	R	0: no Event 1: Event stored
Reserved	P8	Unsigned6	R	R	
Latch1 positive Event	P8	Unsigned1	RW	R	0: no Event 1: Event stored
Latch1 negative Event	P8	Unsigned1	RW	R	0: no Event 1: Event stored
Reserved	P8	Unsigned6	R	R	
Latch 0 positive Edge Value	P9	DWORD	R	R	Latch0 Value positive Event
Latch 0 negative Edge Value	P10	DWORD	R	R	Latch0 Value negative Event
Latch 1 positive Edge Value	P11	DWORD	R	R	Latch1 Value positive Event
Latch 1 negative Edge Value	P12	DWORD	R	R	Latch1 Value negative Event

5.6 CoE coding

5.6.1 PDU structure

The general attribute types of CoE are described in Figure 12.

```
typedef struct
{
    unsigned    NumberLo:    8;
    unsigned    NumberHi:    1;
    unsigned    Reserved:    3;
    unsigned    Service:      4;
} TCOEHEADER;

typedef struct
{
    TMBXHEADER    MbxHeader;
    TCOEHEADER    CoeHeader;
    BYTE          Data[MBX_DATA_SIZE-2];
} TCOEMBX;
```

Figure 12 – CoE general structure

The CoE coding is specified in Table 29.

Table 29 – CoE elements

Frame part	Data Field	Data Type	Value/Description
Mailbox Header	Length	WORD	length of the Mailbox Service Data
	Address	WORD	Station Address of the source, if a master is client, Station Address of the destination, if a slave is client
	Channel	Unsigned6	0x00 (Reserved for future)
	Priority	Unsigned2	0x00: lowest priority ... 0x03: highest priority
	Type	Unsigned4	0x03: CoE
	Cnt	Unsigned3	counter of the mailbox services (0 reserved, 1 is start value, next value after 7 is 1)
	Reserved	Unsigned1	0x00
CoE Header	Number	Unsigned9	depending on the CoE service
	Reserved	Unsigned3	0x00
	Service	Unsigned4	0x01: Emergency 0x02: SDO Request 0x03: SDO Response 0x04: TxPDO 0x05: RxPDO 0x06: TxPDO remote request 0x07: RxPDO remote request 0x08: SDO Information

5.6.2 SDO

5.6.2.1 SDO Download Expedited

5.6.2.1.1 SDO Download Expedited Request

The attribute types of SDO Download Expedited Request are described in Figure 13.

```
typedef struct
{
    unsigned    SizeIndicator:    1;
    unsigned    TransferType:     1;
    unsigned    DataSetSize:      2;
    unsigned    CompleteAccess:   1;
    unsigned    Command:          3;
    BYTE        IndexLo;
    BYTE        IndexHi;
    BYTE        SubIndex;
} TINITSDOHEADER;

typedef struct
{
    TMBXHEADER    MbxHeader;
    TCOEHEADER    CoeHeader;
    TINITSDOHEADER SdoHeader;
    BYTE          Data[4];
} TINITSDDOWNLOADEXPREQMBX;
```

Figure 13 – SDO Download Expedited Request structure

The SDO Download Expedited Request coding is specified in Table 30.

Table 30 – SDO Download Expedited Request

Frame part	Data Field	Data Type	Value/Description
Mailbox Header	Length	WORD	0x0A: Length of the Mailbox Service Data
	Address	WORD	Station Address of the source, if a master is client, Station Address of the destination, if a slave is client
	Channel	Unsigned6	0x00 (Reserved for future)
	Priority	Unsigned2	0x00: lowest priority ... 0x03: highest priority
	Type	Unsigned4	0x03: CoE
	Cnt	Unsigned3	counter of the mailbox services (0 reserved, 1 is start value, next value after 7 is 1)
	Reserved	Unsigned1	0x00
CoE Header	Number	Unsigned9	0x00
	Reserved	Unsigned3	0x00
	Service	Unsigned4	0x02: SDO Request
SDO	Size Indicator	Unsigned1	0x01: size of Data in Data Set Size specified
	Transfer Type	Unsigned1	0x01: Expedited transfer
	Data Set Size	Unsigned2	0x00: 4 Octet Data 0x01: 3 Octet Data 0x02: 2 Octet Data 0x03: 1 Octet Data
	Complete Access	Unsigned1	0x00: entry addressed with index and subindex will be downloaded 0x01: complete object will be downloaded, subindex shall be zero (subindex 0 included) or one (subindex 0 excluded)
	Command Specifier	Unsigned3	0x01: Download Request
	Index	WORD	index of the Object
	Subindex	BYTE	subindex of the Object, shall be zero or one if Complete Access = 0x01
	Data	BYTE[4]	data of the Object Unused octets should be 0

5.6.2.1.2 SDO Download Expedited Response

The attribute types of SDO Download Expedited Response are described in Figure 14.

```
typedef struct
{
    TMBXHEADER      MbxHeader;
    TCOEHEADER      CoeHeader;
    TINITSDOHEADER  SdoHeader;
} TINITSDDOWNLOADEXPRESMBX;
```

Figure 14 – SDO Download Expedited Response structure

The SDO Download Expedited Response coding is specified in Table 31.

Table 31 – SDO Download Expedited Response

Frame part	Data Field	Data Type	Value/Description
Mailbox Header	Length	WORD	0x0A: Length of the Mailbox Service Data
	Address	WORD	Station Address of the source, if a master is client, Station Address of the destination, if a slave is client
	Channel	Unsigned6	0x00 (Reserved for future)
	Priority	Unsigned2	0x00: lowest priority ... 0x03: highest priority
	Type	Unsigned4	0x03: CoE
	Cnt	Unsigned3	counter of the mailbox services (0 reserved, 1 is start value, next value after 7 is 1)
	Reserved	Unsigned1	0x00
CoE Header	Number	Unsigned9	0x00
	Reserved	Unsigned3	0x00
	Service	Unsigned4	0x03: SDO Response
SDO	Size Indicator	Unsigned1	0x00
	Transfer Type	Unsigned1	0x00
	Data Set Size	Unsigned2	0x00
	Complete Access	Unsigned1	Don't care (recommend value 0)
	Command Specifier	Unsigned3	0x03: Download Response
	Index	WORD	index of the Object
	Subindex	BYTE	subindex of the Object, shall be zero or one if Complete Access = 0x01
	reserved	DWORD	

5.6.2.2 SDO Download Normal

5.6.2.2.1 SDO Download Normal Request

The attribute types of SDO Download Normal Request are described in Figure 15.

```
typedef struct
{
    TMBXHEADER      MbxHeader;
    TCOEHEADER      CoeHeader;
    TINITSDOHEADER  SdoHeader;
    DWORD           CompleteSize;
    BYTE            Data[MBX_DATA_SIZE-10];
} TINITSDODOWNLOADNORMREQMBX;
```

Figure 15 – SDO Download Normal Request structure

The SDO Download Normal Request coding is specified in Table 32.

Table 32 – SDO Download Normal Request

Frame part	Data Field	Data Type	Value/Description
Mailbox Header	Length	WORD	n >= 0x0A: Length of the Mailbox Service Data
	Address	WORD	Station Address of the source, if a master is client, Station Address of the destination, if a slave is client
	Channel	Unsigned6	0x00 (Reserved for future)
	Priority	Unsigned2	0x00: lowest priority ... 0x03: highest priority
	Type	Unsigned4	0x03: CoE
	Cnt	Unsigned3	counter of the mailbox services (0 reserved, 1 is start value, next value after 7 is 1)
	Reserved	Unsigned1	0x00
CoE Header	Number	Unsigned9	0x00
	Reserved	Unsigned3	0x00
	Service	Unsigned4	0x02: SDO Request
SDO	Size Indicator	Unsigned1	0x01
	Transfer Type	Unsigned1	0x00: Normal transfer
	Data Set Size	Unsigned2	0x00
	Complete Access	Unsigned1	0x00: entry addressed with index and subindex will be downloaded 0x01: complete object will be uploaded, subindex shall be zero (subindex 0 included) or one (subindex 0 excluded)
	Command Specifier	Unsigned3	0x01: Download Request
	Index	WORD	index of the Object
	Subindex	BYTE	subindex of the Object, shall be zero or one if Complete Access = 0x01
	Complete Size	DWORD	complete Data Size of the Object
	Data	BYTE[n-10]	if ((Length-10) >= Complete Size): Data of the Object if ((Length-10) < Complete Size): First Data part of the Object, Download SDO Segment is following

5.6.2.2.2 SDO Download Normal Response

The attribute types and coding of SDO Download Normal Response are the same as of SDO Download Expedited Response (see 5.6.2.1.2).

5.6.2.3 Download SDO Segment

5.6.2.3.1 Download SDO Segment Request

The attribute types of Download SDO Segment Request are described in Figure 16.