

BS EN 61158-6-15:2012



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Industrial communication networks — Fieldbus specifications

Part 6-15: Application layer protocol specification — Type 15 elements

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National foreword

This British Standard is the UK implementation of EN 61158-6-15:2012. It is identical to IEC 61158-6-15:2010. It supersedes BS EN 61158-6-15:2008 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AMT/7, Industrial communications: process measurement and control, including fieldbus.

A list of organizations represented on this committee can be obtained on request to its secretary.

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**Industrial communication networks -
Fieldbus specifications -
Part 6-15: Application layer protocol specification -
Type 15 elements
(IEC 61158-6-15:2010)**

Réseaux de communication industriels -
Spécifications des bus de terrain -
Partie 6-15: Spécification des protocoles
des couches d'application -
Éléments de type 15
(CEI 61158-6-15:2010)

Industrielle Kommunikationsnetze -
Feldbusse -
Teil 6-15: Protokollspezifikation des
Application Layer (Anwendungsschicht) -
Typ 15-Elemente
(IEC 61158-6-15:2010)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 65C/607/FDIS, future edition 2 of IEC 61158-6-15, prepared by SC 65C, "Industrial networks", of IEC/TC 65, "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61158-6-15:2012.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2012-12-28
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-03-28

This document supersedes EN 61158-6-15:2008.

EN 61158-6-15:2012 includes the following significant technical changes with respect to EN 61158-6-15:2008:

- editorial corrections.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 61158-6-15:2010 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC/TR 61158-1:2010 NOTE Harmonized as CLC/TR 61158-1:2010 (not modified).

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61158-5-15	2010	Industrial communication networks - Fieldbus specifications - Part 5-15: Application layer service definition - Type 15 elements	EN 61158-5-15	2012
ISO/IEC 7498-1	-	Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model	-	-
ISO/IEC 8822	-	Information technology - Open Systems Interconnection - Presentation service definition	-	-
ISO/IEC 8824-1	-	Information technology - Abstract Syntax Notation One (ASN.1): Specification of basic notation	-	-
ISO/IEC 9545	-	Information technology - Open Systems Interconnection - Application Layer structure	-	-

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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 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 standard 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 implementers 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 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 6-15: Application layer protocol specification – Type 15 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 standard 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 15 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 standard defines in an abstract way the externally visible behavior provided by the Type 15 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 standard is to define the protocol provided to

- a) define the wire-representation of the service primitives defined in IEC 61158-5-15, and
- b) define the externally visible behavior associated with their transfer.

This standard specifies the protocol of the Type 15 IEC fieldbus Application Layer, in conformance with the OSI Basic Reference Model (ISO/IEC 7498) and the OSI Application Layer Structure (ISO/IEC 9545).

1.2 Specifications

The principal objective of this standard is to specify the syntax and behavior of the application layer protocol that conveys the application layer services defined in IEC 61158-5-15.

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 IEC 61158-6.

1.3 Conformance

This standard does not specify individual implementations or products, nor does it constrain the implementations of application layer entities within industrial automation systems. Conformance is achieved through implementation of this application layer protocol specification.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 61158-5-15:2010¹, *Industrial communication networks – Fieldbus specifications - Part 5-15: Application layer service definition – Type 15 elements*

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

ISO/IEC 8822, *Information technology – Open Systems Interconnection – Presentation service definition*

ISO/IEC 8824-1, *Information technology – Abstract Syntax Notation One (ASN.1): Specification of basic notation*

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

3 Terms and definitions, abbreviations, symbols and conventions

3.1 Terms and definitions

For the purposes of this document, the following terms as defined in these publications apply:

3.1.1 ISO/IEC 7498-1 terms

- a) application entity
- b) application process
- c) application protocol data unit
- d) application service element
- e) application entity invocation
- f) application process invocation
- g) application transaction
- h) real open system
- i) transfer syntax

3.1.2 ISO/IEC 8822 terms

- a) abstract syntax
- b) presentation context

¹ To be published.

3.1.3 ISO/IEC 9545 terms

- a) application-association
- b) application-context
- c) application context name
- d) application-entity-invocation
- e) application-entity-type
- f) application-process-invocation
- g) application-process-type
- h) application-service-element
- i) application control service element

3.1.4 ISO/IEC 8824-1 terms

- a) object identifier
- b) type

3.1.5 IEC/TR 61158-1 terms

The following IEC/TR 61158-1 terms apply.

3.1.5.1

application

function or data structure for which data is consumed or produced

3.1.5.2

application layer interoperability

capability of application entities to perform coordinated and cooperative operations using the services of the FAL

3.1.5.3

application object

object class that manages and provides the run time exchange of messages across the network and within the network device

NOTE Multiple types of application object classes may be defined.

3.1.5.4

application process

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

3.1.5.5

application process identifier

distinguishes multiple application processes used in a device

3.1.5.6

application process object

component of an application process that is identifiable and accessible through an FAL application relationship

NOTE Application process object definitions are composed of a set of values for the attributes of their class.

3.1.5.7

application process object class

class of application process objects defined in terms of the set of their network-accessible attributes and services

3.1.5.8

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

3.1.5.9

application relationship endpoint

context and behavior of an application relationship as seen and maintained by one of the application processes involved in the application relationship

NOTE Each application process involved in the application relationship maintains its own application relationship endpoint.

3.1.5.10

application service element

application-service-element that provides the exclusive means for establishing and terminating all application relationships

3.1.5.11

attribute

description of an externally visible characteristic or feature of an object

NOTE 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.

3.1.5.12

behavior

indication of how the object responds to particular events

NOTE Its description includes the relationship between attribute values and services.

3.1.5.13

class

set of objects, all of which represent the same kind of system component

NOTE A class is a generalization of the object; a template for defining variables and methods. All objects in a class are identical in form and behavior, but usually contain different data in their attributes.

3.1.5.14

class attributes

attribute that is shared by all objects within the same class

3.1.5.15

class code

unique identifier assigned to each object class

3.1.5.16

class specific service

service defined by a particular object class to perform a required function which is not performed by a common service

NOTE A class specific object is unique to the object class which defines it.

3.1.5.17

Client

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

- (b) initiator of a message to which a server reacts, such as the role of an AR endpoint in which it issues confirmed service request APDUs to a single AR endpoint acting as a server

3.1.5.18
conveyance path

unidirectional flow of APDUs across an application relationship

3.1.5.19
cyclic

term used to describe events which repeat in a regular and repetitive manner

3.1.5.20
dedicated AR

AR used directly by the FAL user

NOTE On Dedicated ARs, only the FAL Header and the user data are transferred.

3.1.5.21
device

physical hardware connection to the link

NOTE A device may contain more than one node.

3.1.5.22
device profile

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

3.1.5.23
dynamic AR

AR that requires the use of the AR establishment procedures to place it into an established state

3.1.5.24
endpoint

one of the communicating entities involved in a connection

3.1.5.25
error

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

3.1.5.26
error class

general grouping for error definitions

NOTE Error codes for specific errors are defined within an error class.

3.1.5.27
error code

identification of a specific type of error within an error class

3.1.5.28
FAL subnet

networks composed of one or more data link segments

NOTE Subnets are permitted to contain bridges, but not routers. FAL subnets are identified by a subset of the network address.

3.1.5.29

logical device

FAL class that abstracts a software component or a firmware component as an autonomous self-contained facility of an automation device

3.1.5.30

management information

network-accessible information that supports managing the operation of the fieldbus system, including the application layer

NOTE Managing includes functions such as controlling, monitoring, and diagnosing.

3.1.5.31

network

series of nodes connected by some type of communication medium

NOTE The connection paths between any pair of nodes can include repeaters, routers and gateways.

3.1.5.32

peer

role of an AR endpoint in which it is capable of acting as both client and server

3.1.5.33

pre-defined AR endpoint

AR endpoint that is defined locally within a device without use of the create service

NOTE Pre-defined ARs that are not pre-established are established before being used.

3.1.5.34

pre-established AR endpoint

AR endpoint that is placed in an established state during configuration of the AEs that control its endpoints

3.1.5.35

Publisher

role of an AR endpoint in which it transmits APDUs onto the fieldbus for consumption by one or more subscribers

NOTE The publisher may not be aware of the identity or the number of subscribers and it may publish its APDUs using a dedicated AR. Two types of publishers are defined by this standard, Pull Publishers and Push Publishers, each of which is defined separately.

3.1.5.36

server

a) role of an AREP in which it returns a confirmed service response APDU to the client that initiated the request

b) object which provides services to another (client) object

3.1.5.37

service

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

NOTE A set of common services is defined and provisions for the definition of object-specific services are provided. Object-specific services are those which are defined by a particular object class to perform a required function which is not performed by a common service.

3.1.5.38

subscriber

role of an AREP in which it receives APDUs produced by a publisher

NOTE Two types of subscribers are defined by this standard, pull subscribers and push subscribers, each of which is defined separately.

3.1.6 Specific definitions for client/server

3.1.6.1

coils, discrete outputs

application process object, a set of coils, characterized by the address of a coil and a quantity of coils, this set is also called discrete outputs when associated with field outputs

3.1.6.2

discrete, discrete input

application process object, addressed by an unsigned number and having a width of one bit, representing a 1-bit encoded status value, read-only, with the value '1' encoding the status ON and the value '0' encoding the status OFF, also called discrete input, especially when associated with field inputs

3.1.6.3

discrete inputs, discretetes

application process object, a set of discretetes, characterized by the address of a discrete and a quantity of discretetes, this set is also called discrete inputs, especially when associated with field inputs

3.1.6.4

coil, discrete output

application process object, addressed by an unsigned number and having a width of one bit, representing a 1-bit encoded status value, read-write, with the value '1' encoding the status ON and the value '0' encoding the status OFF, also called discrete output when associated with field output

3.1.6.5

encapsulated interface

mechanism encapsulating a service for an interface, which is an application process object characterized by an MEI type

3.1.6.6

exception

encoding used to signal a service request failure

3.1.6.7

exception code

encoding associated with an exception, detailing the reason of a service request failure

3.1.6.8

file

application process object, an organization of records, characterized by an unsigned number

3.1.6.9

function code

encoding of a service requested to a server

3.1.6.10

holding register, output register

application process object, addressed by an unsigned number and representing values with 16 bits, read-write, also called output register, especially when associated with field outputs

3.1.6.11

holding registers, output registers

application process object, a set of holding registers, characterized by the address of a holding register and a quantity of holding registers, also called output registers, especially when associated with field outputs

3.1.6.12

input register

application process object, addressed by an unsigned number and representing values with 16 bits, read-only

3.1.6.13

input registers

application process object, a set of input registers, characterized by the address of an input register and a quantity of input registers

3.1.6.14

record

application process object, a set of contiguous registers of a specified type, characterized by the address of the first register and by the quantity of registers; in the context of this definition, the registers involved have also been called references

3.1.6.15

reference

denigrated term for register

3.1.6.16

reference type

denigrated term for register type

3.1.6.17

sub-code

specialization of a function code

3.1.6.18

unit ID

logical device identifier

3.1.6.19

MEI type

type specified as an octet value, used to dispatch a service to the appropriate interface in the context of the encapsulated interface mechanism

3.1.7 Specific definitions for publish/subscribe

3.1.7.1

network object

Publish/subscribe application, reader, or writer

3.1.7.2

GUID

globally unique network object identifier

3.1.7.3

composite state

attributes of a set of network objects

3.1.7.4

reader

subscriber or a CSTReader

3.1.7.5

writer

Publisher or a CSTWriter

3.1.7.6

CSTReader

meta-information-specialized subscriber

3.1.7.7

CSTWriter

meta-information-specialized publisher

3.1.7.8

communication actor

reader or writer

3.1.7.9

domain participant

application that contains publish/subscribe elements, also called publish/subscribe application

NOTE This terminology is adopted to avoid the overuse of the term “application”. At the same time, the term “domain” has a place within publish/subscribe. The Type extensibility allows for the concept of “domains”, or independent communication planes, effectively permitting isolation of application exchanges within domains. While OMG DDS as in “Data Distribution Service for Real-Time Systems Specification, Version 1.1, December 2005” uses this extension, the feature will not be examined further in this specification, which will consider a single domain.

3.1.7.10

manager

specialized publish/subscribe application, containing specialized publishers and subscribers, and involved in the described discovery and maintenance mechanism; not to be confused with any publishing manager

3.1.7.11

managed participant

a publish/subscribe application; the qualifier refers to its role in relation to a manager when involved in the described discovery and maintenance mechanism; not to be confused with any publishing manager subordinate

3.1.7.12

sequence number

number used to uniquely identify elementary publish/subscribe messages in an ordered manner

3.2 Abbreviations and symbols

3.2.1 Common abbreviations and symbols

AE	Application Entity
AL	Application Layer
ALME	Application Layer Management Entity
ALP	Application Layer Protocol
APO	Application Object
AP	Application Process
APDU	Application Protocol Data Unit

API	Application Process Identifier
AR	Application Relationship
AREP	Application Relationship End Point
ASCII	American Standard Code for Information Interchange
ASE	Application Service Element
Cnf	Confirmation
DL-	(as a prefix) data-link-
DLC	data-link Connection
DLCEP	data-link Connection End Point
DLL	data-link Layer
DLM	data-link-management
DLSAP	data-link Service Access Point
DLSDU	DL-service-data-unit
FAL	Fieldbus Application Layer
ID	Identifier
IEC	International Electrotechnical Commission
Ind	Indication
LME	Layer Management Entity
lsb	Least Significant Bit
msb	Most Significant Bit
OSI	Open Systems Interconnect
QoS	Quality of Service
Req	Request
Rsp	Response
SAP	Service Access Point
SDU	Service Data Unit
SMIB	System Management Information Base
SMK	System Management Kernel

3.2.2 Abbreviations and symbols for client/server

C/S	Client/Server
FC	Function Code
CAN	Controller Area Network
CiA	CAN in Automation
MEI	Encapsulated Interface type
URL	Uniform Resource Locator

3.2.3 Abbreviations and symbols for publish/subscribe

CS	Composite State
DCPS	Data-Centric Publish-Subscribe
DDS	Data Distribution Service
DLRL	Data Local Reconstruction Layer
OMG	Object Management Group
P/S	Publish/Subscribe

3.3 Conventions

3.3.1 Overview

The FAL is defined as a set of object-oriented ASEs. Each ASE is specified in a separate subclause. Each ASE specification is composed of two parts, its class specification, and its service specification.

The class specification defines the attributes of the class. The attributes are accessible from instances of the class using the Object Management ASE services specified in Clause 5 of this standard. The service specification defines the services that are provided by the ASE.

3.3.2 General conventions

This standard uses the descriptive conventions given in ISO/IEC 10731

3.3.3 Conventions for class definitions

Class definitions are described using templates. Each template consists of a list of attributes for the class. The general form of the template is shown below:

```

FAL ASE:    ASE Name
CLASS:Class Name
CLASS ID:  #
PARENT CLASS:      Parent Class Name
ATTRIBUTES:
1      (o)  Key Attribute: numeric identifier
2      (o)  Key Attribute: name
3      (m)  Attribute:    attribute name(values)
4      (m)  Attribute:    attribute name(values)
4.1    (s)  Attribute:    attribute name(values)
4.2    (s)  Attribute:    attribute name(values)
4.3    (s)  Attribute:    attribute name(values)
5      (c)  Constraint:   constraint expression
5.1    (m)  Attribute:    attribute name(values)
5.2    (o)  Attribute:    attribute name(values)
6      (m)  Attribute:    attribute name(values)
6.1    (s)  Attribute:    attribute name(values)
6.2    (s)  Attribute:    attribute name(values)
SERVICES:
1      (o)  OpsService:   service name
2      (c)  Constraint:   constraint expression
2.1    (o)  OpsService:   service name
3      (m)  MgtService:   service name
    
```

- (1) The "FAL ASE:" entry is the name of the FAL ASE that provides the services for the class being specified.
- (2) The "CLASS:" entry is the name of the class being specified. All objects defined using this template will be an instance of this class. The class may be specified by this standard, or by a user of this standard.
- (3) The "CLASS ID:" entry is a number that identifies the class being specified. This number is unique within the FAL ASE that will provide the services for this class. When qualified by the identity of its FAL ASE, it unambiguously identifies the class within the scope of the FAL. The value "NULL" indicates that the class cannot be instantiated. Class IDs between 1 and 255 are reserved by this standard to identify standardized classes. They have been assigned to maintain compatibility with existing national standards. CLASS IDs between 256 and 2 048 are allocated for identifying user defined classes.
- (4) The "PARENT CLASS:" entry is the name of the parent class for the class being specified. All attributes defined for the parent class and inherited by it are inherited for

the class being defined, and therefore do not have to be redefined in the template for this class.

NOTE The parent-class "TOP" indicates that the class being defined is an initial class definition. The parent class TOP is used as a starting point from which all other classes are defined. The use of TOP is reserved for classes defined by this standard.

- (5) The "ATTRIBUTES" label indicate that the following entries are attributes defined for the class.
- a) Each of the attribute entries contains a line number in column 1, a mandatory (m) / optional (o) / conditional (c) / selector (s) indicator in column 2, an attribute type label in column 3, a name or a conditional expression in column 4, and optionally a list of enumerated values in column 5. In the column following the list of values, the default value for the attribute may be specified.
 - b) Objects are normally identified by a numeric identifier or by an object name, or by both. In the class templates, these key attributes are defined under the key attribute.
 - c) The line number defines the sequence and the level of nesting of the line. Each nesting level is identified by period. Nesting is used to specify
 - i) fields of a structured attribute (4.1, 4.2, 4.3),
 - ii) attributes conditional on a constraint statement (5). Attributes may be mandatory (5.1) or optional (5.2) if the constraint is true. Not all optional attributes require constraint statements as does the attribute defined in (5.2).
 - iii) the selection fields of a choice type attribute (6.1 and 6.2).
- (6) The "SERVICES" label indicates that the following entries are services defined for the class.
- a) An (m) in column 2 indicates that the service is mandatory for the class, while an (o) indicates that it is optional. A (c) in this column indicates that the service is conditional. When all services defined for a class are defined as optional, at least one has to be selected when an instance of the class is defined.
 - b) The label "OpsService" designates an operational service (1).
 - c) The label "MgtService" designates a management service (2).
 - d) The line number defines the sequence and the level of nesting of the line. Each nesting level is identified by period. Nesting within the list of services is used to specify services conditional on a constraint statement.

3.3.4 Conventions for service definitions

3.3.4.1 General

The FAL is defined as a set of object-oriented ASEs. Each ASE is specified in a separate subclause. Each ASE specification is composed of three parts: its class definitions, its services, and its protocol specification. The first two are contained in IEC 61158-5-15. The protocol specification for each of the ASEs is defined in this standard.

The class definitions define the attributes of the classes supported by each ASE. The attributes are accessible from instances of the class using the Management ASE services specified in IEC 61158-5-15. The service specification defines the services that are provided by the ASE.

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

3.3.5 Conventions for class definitions

The data-link layer mapping definitions are described using templates. Each template consists of a list of attributes for the class. The general form of the template is defined in IEC/TR 61158-1.

3.3.6 Abstract syntax conventions

When the "optionalParametersMap" parameter is used, a bit number which corresponds to each OPTIONAL or DEFAULT production is given as a comment.

3.4 Conventions used in state machines

The state machines are described in Table 1:

Table 1 – Conventions used for state machines

#	Current state	Event / condition => action	Next state
Name of this transition.	The current state to which this state transition applies.	Events or conditions that trigger this state transaction. => The actions that are taken when the above events or conditions are met. The actions are always indented below events or conditions.	The next state after the actions in this transition is taken.

The conventions used in the state machines are as follows:

:= 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.

xxx A parameter name.

EXAMPLE 1

Identifier := reason
means value of a 'reason' parameter is assigned to a parameter called 'Identifier.'

"xxx" Indicates fixed value.

EXAMPLE 2

Identifier := "abc"
means value "abc" is assigned to a parameter named 'Identifier.'

- =** 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"

This construct allows the execution of a sequence of actions in a loop within one transition. The loop is executed for all values from start_value to end_value.

EXAMPLE 3

```
for (Identifier := start_value to end_value)
  actions
endfor
```

This construct allows the execution of alternative actions depending on some condition (which might be the value of some identifier or the outcome of a previous action) within one transition.

```
EXAMPLE 4
  If (condition)
    actions
  else
    actions
  endif
```

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

4 Abstract syntax for client/server

The abstract syntax of APDUs is combined with their transfer syntax and is specified in Clause 5.

5 Transfer syntax for client/server

5.1 General

The sending Application Layer prepares an APDU to transfer to the receiving Application Layer. It uses the parameters from the service primitives to do so. There are several formats of the APDU:

- request APDU from Client to Server device or devices, or
- normal response and positive confirmation from Server to Client device, or
- response and negative confirmation from Server to Client device.

The format and coding rules for all APDUs are specified in this clause.

5.2 Common APDU structure

All APDUs have a common structure as shown in Figure 1.

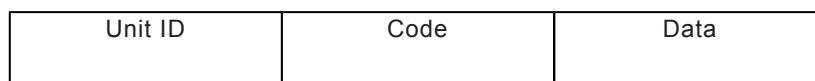


Figure 1 – APDU Format

5.2.1 Unit ID

Client/server devices in the role of servers are addressed using a Unit ID. The Unit ID needs to be unique across all the servers addressable by a client. The set of addressable servers is determined by the underlying layer. This set is sometimes called connection.

The Unit ID assignment is outside of the scope of this specification.

The Unit ID identifies logical devices. There may be more than one logical device per physical device.

Some values of Unit ID are reserved and have particular meanings. The value 0 is reserved for broadcast.

Field Type: Unsigned8

Allowed values: 1 to 247, and 0 for broadcast where supported.

NOTE In general the Unit ID is only required for logical devices having the role of servers. Often logical devices can have either role or multiple roles, via configuration, and their Unit ID is not used when they only perform in the client role. Depending on the underlying layers some devices can have concurrently a client and a server role on the same access point, this is the case for client/server on Token Bus/HDLC, outside the scope of this specification.

5.2.2 Code

5.2.2.1 General

This field represents:

- a requested service, confirmed or unconfirmed, via an identifier called function code, or
- the normal response and positive confirmation of a requested service, represented by echoing the requested service identifier, or
- the exception response and negative confirmation of a requested service, represented by echoing the requested service identifier with its high bit turned on. The latter representation is also called exception.

Field Type: Unsigned8

5.2.2.2 Service identifiers and function codes

Client/server service identifiers are commonly called function codes.

Function codes are encodings of services requested to a server. Some function codes are further specialized by means of a sub-code, specified as part of the data field. These encodings are partitioned in three categories, and since the subdivision may propagate to the sub-codes, for sake of completeness, despite being part of the data field they will also be mentioned here:

Publicly assigned function codes

These function codes are either assigned to a standard service or reserved for future assignment. The standard services and their identifiers will be detailed in this specification.

User definable function codes

These function codes can be used for experimentation in a controlled laboratory environment. They must not be used in an open environment.

Ranges: There are two ranges, FC 65 (0x41) to 72 (0x48) included, and 100 (0x64) to 110 (0x6E) included.

Reserved function codes

These function codes are currently used by some companies for legacy products and are not available for public use.

NOTE 1 Function code assignments are managed by the Modbus-IDA industrial consortium.

NOTE 2 The following function codes, while publicly assigned, are not covered by this specification: FC 7 (0x07, Read Exception Status), FC 8 (0x08, Diagnostics), FC 11 (0x0B, Get Com Event Counter), FC 12 (0x0C, Get Com Event Log), FC 17 (0x11, Report Slave ID).

NOTE 3 The following function codes and function code/sub-codes are reserved: FC 8/19 (0x08/0x13), FC 8/21-255 (0x08/0x15-0xFFFF), FC 9 (0x09), FC 10 (0x0A), FC 13 (0x0D), FC 14 (0x0E), FC 41 (0x29), FC 42 (0x2A), FC 43/0-12 (0x2B/0x00-0x0C), FC 43/15-255 (0x2B/0x0F-0xFF), FC 90 (0x5A), FC 91 (0x5B), FC 125 (0x7D), FC 126 (0x7E), FC 127 (0x7F).

5.2.3 Data

For normal requests and responses this is the user data which is transferred between the application layer and its user. The application layer assembles it from the parameters of a service primitive or parses it into parameters of a service primitive. Its structure depends upon the type of APDU. For exception responses it represents the reason for the exception via an exception code.

Field Type: from 1 to 252 octets; the Type is APDU specific.

5.2.4 Client to server confirmed service request

The format is as in Figure 2.

Unit ID	Function code	Request Data
---------	---------------	--------------

Figure 2 – Client to server confirmed service request

5.2.5 Normal response from server to client

The format for the normal response to a confirmed service is as in Figure 3. The Unit ID and the function code fields are the same as the corresponding fields in the request.

Unit ID	Function code	Response Data
---------	---------------	---------------

Figure 3 – Normal response from server to client

5.2.6 Exception response from server to client

The format for the exception response is as in Figure 4. The Unit ID is the same as the corresponding field in the request. The exception is produced adding 0x80 to the function code of the corresponding request.

Unit ID	Exception	Exception code
---------	-----------	----------------

Figure 4 – Exception response from server to client

The exception codes, giving information on the service failure, are shown in Table 2.

Table 2 – Exception code

Encoding	Name	Description
0x01	Illegal function	The function code received in the query is not an allowable action for the server. This may be because the function code is only applicable to newer devices, and was not implemented in the unit selected. It could also indicate that the server is in the wrong state to process a request of this type, for example because it is not configured and it is being asked to return register values
0x02	Illegal data address	The data address received in the query is not an allowable address for the server. More specifically, the combination of reference number and transfer length is invalid. Example For a controller with 100 registers, a request with offset (data address) 96 and length 4 would succeed, a request with offset 96 and length 5 would generate exception code 0x02
0x03	Illegal data value	A value contained in the query data field is not an allowable value for server. This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It specifically does NOT mean for example that a data item submitted for storage in a register has a value outside the expectation of the application program, since the client/server protocol is unaware of the significance of any particular value for any particular register
0x04	Server device failure	An unrecoverable error occurred while the server was attempting to perform the requested action
0x05	Acknowledge	The server accepted the service invocation but the service requires a relatively long time to execute. The server therefore returns only an acknowledgement of the service invocation receipt. This response is returned to prevent a timeout error from occurring in the client
0x06	Server busy	The server was unable to accept the request. The client application has the responsibility of deciding if and when to re-send the request
0x08	Memory parity error	For specialized use in conjunction with function codes 20 (0x14) and 21 (0x15), to indicate that the extended file area failed to pass a consistency check. For example, the server attempted to read record file, but detected a memory parity error. The client can retry the request, but service may be required on the server device
0x0A	Gateway path unavailable	For specialized use in conjunction with gateways, hubs, switches and similar network devices, to indicate that the gateway was unable to allocate an internal communication path from the input port to the output port for processing the request. This usually means that the gateway is misconfigured or overloaded
0x0B	Gateway target device failed to respond	For specialized use in conjunction with gateways, hubs, switches and similar network devices, to indicate that no response was obtained from the target device. This usually means that the device is not present on the network

5.2.7 Client to server unconfirmed service request

The format is as in Figure 5. These services are used for broadcast. Only a small number of function codes allow broadcast.

Unit ID = 0	Function code	Request Data
-------------	---------------	--------------

Figure 5 – Client to server unconfirmed service request

5.3 Service-specific APDU structures

5.3.1 Read Discretes FAL PDU

5.3.1.1 Request primitive

Service identifier, function code = 2 (0x02).

This function code is used to read the status of 1 to 2 000 discrete inputs in a remote device. The request PDU specifies the starting address, i.e. the address of the first input specified, and the number of inputs. In the PDU Discrete Inputs are addressed starting at zero. Therefore discrete inputs numbered 1 to 16 are addressed as 0 to 15. The starting address can be from 0x0000 to 0xFFFF.

The format is given in Table 3.

Table 3 – Read discretes request

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Allowed values: 1 to 247
Function code	Unsigned8	Service identifier, function code = 2 (0x02).
Address of first discrete	Unsigned16	Address of the first discrete input. Allowed values: 0x0000 to 0xFFFF
Quantity of discretes	Unsigned16	Quantity of discretes. Allowed values: 1 to 2 000 (0x7D0)

5.3.1.2 Response primitive

The format is given in Table 4.

Table 4 – Read discretes response

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Echo of requested
Function code	Unsigned8	Service identifier, function code = 2 (0x02). Echo of requested
Data octets count	Unsigned16	Number of octets read
Data	Status bit sequence	Status values of the discretes read

The field data contains n octets where n is the number in the field data octets count.

The discrete inputs in the response message are packed as one input per bit of the data field. Status is indicated as 1= ON; 0= OFF. The lsb (least significant bit) of the first data octet contains the input addressed in the query. The other inputs follow toward the high order end of this octet, and from low order to high order in subsequent octets.

If the returned input quantity is not a multiple of eight, the remaining bits in the final data octet shall be padded with zeros (toward the high order end of the octet). The data octets count field specifies the quantity of octets of returned inputs data, n (including the padded octet, if any).

5.3.2 Read Coils FAL PDU

5.3.2.1 Request primitive

Service identifier, function code = 1 (0x01).

This function code is used to read from 1 to 2 000 coils in a remote device. The request PDU specifies the starting address, i.e. the address of the first coil specified, and the number of coils. In the PDU, coils are addressed starting at zero. Therefore coils numbered 1 to 16 are addressed as 0 to 15. The starting address can be from 0x0000 to 0xFFFF.

The format is given in Table 5.

Table 5 – Read coils request

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Allowed values: 1 to 247
Function code	Unsigned8	Service identifier, function code = 1 (0x01).
Address of first coil	Unsigned16	Address of the first coil. Allowed values: 0x0000 to 0xFFFF
Quantity of coils	Unsigned16	Quantity of coils. Allowed values: 1 to 2 000 (0x7D0)

5.3.2.2 Response primitive

The format is given in Table 6.

Table 6 – Read coils response

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Echo of requested
Function code	Unsigned8	Service identifier, function code = 1 (0x01). Echo of requested
Data octets count	Unsigned16	Number of octets read
Data	Status bit sequence	Status values of the discretes read

The field data contains n octets where n is the number in the field data octets count.

The coils in the response message are packed as one input per bit of the data field. Status is indicated as 1= ON; 0= OFF. The lsb (least significant bit) of the first data octet contains the input addressed in the query. The other coils follow toward the high order end of this octet, and from low order to high order in subsequent octets.

If the returned input quantity is not a multiple of eight, the remaining bits in the final data octet shall be padded with zeros (toward the high order end of the octet). The data octets count field specifies the quantity of octets of returned inputs data, n (including the padded octet, if any).

5.3.3 Write Single Coil FAL PDU

5.3.3.1 Request primitive

Service identifier, function code = 5 (0x05).

This function code is used to write a single coil to either ON or OFF in a remote device.

The requested ON/OFF status is specified by a constant in the request data field. A value of 0xFF00 requests the output to be ON. A value of 0x0000 requests it to be OFF. All other values are illegal and do not affect the output.

The Request PDU specifies the address of the coil to be forced. Coils are addressed starting at zero. Therefore coil numbered 1 is addressed as 0.

The format is given in Table 7.

Table 7 – Write single coil request

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Allowed values: 1 to 247
Function code	Unsigned8	Service identifier, function code = 5 (0x05).
Address of coil	Unsigned16	Address of the coil. Allowed values: 0x0000 to 0xFFFF
Data single coil	Status flag	Single coil status value that has to be written. Allowed values: 0xFF00 or 0x0000

5.3.3.2 Response primitive

The format is given in Table 8.

Table 8 – Write single coil response

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Echo of requested.
Function code	Unsigned8	Service identifier, function code = 5 (0x05). Echo of requested.
Address of coil	Unsigned16	Address of the coil. Echo of requested.
Data single coil	Status flag	Single coil status value that had to be written. Echo of requested.

The normal response is an echo of the request, returned after the coil state has been written.

5.3.4 Write Multiple Coils FAL PDU

5.3.4.1 Request primitive

Service identifier, function code = 15 (0x0F).

This function code is used to force each coil in a sequence of coils to either ON or OFF in a remote device.

The Request PDU specifies the coil references to be forced. Coils are addressed starting at zero. Therefore coil numbered 1 is addressed as 0.

The requested ON/OFF coils status is specified by the contents of the request data field. A logical '1' in a bit position of the field requests the corresponding output to be ON. A logical '0' requests it to be OFF.

The coils in the request message are packed as one input per bit of the data field. If the specified quantity of coils is not a multiple of eight, the remaining bits in the final data octet of data shall be padded with zeros (toward the high order end of the octet). The octet count field specifies the quantity of octets of data, n (including the padded octet, if any). The field data contains the n data octets, where n is the number in the field octet count.

The format is given in Table 9.

Table 9 – Write multiple coils request

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Allowed values: 1 to 247
Function code	Unsigned8	Service identifier, function code = 15 (0x0F).
Address of first coil	Unsigned16	Address of the first coil. Allowed values: 0x0000 to 0xFFFF
Quantity of coils	Unsigned16	Quantity of coils to be written. Allowed values: 1 to 1 968 (0x7B0), must be consistent with the Data octets count and the Data parameters
Data octets count	Unsigned16	Number of octets carrying the coil status values to be written. Allowed values: 1 to 246, must be consistent with the Quantity of coils and the Data parameters
Data	Status bit sequence	This parameter shall be used to specify the coil status values that have to be written. Allowed values: Must be consistent with the Quantity of coils and the Data octets count parameters

5.3.4.2 Response primitive

The format is given in Table 10.

Table 10 – Write multiple coils response

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Echo of requested
Function code	Unsigned8	Service identifier, function code = 15 (0x0F)
Address of first coil	Unsigned16	Address of the first coil. Echo of requested
Quantity of coils	Unsigned16	Quantity of coils. Echo of requested

The normal response is an echo of the requested parameters Unit ID, function code, address of first coil, and quantity of coils.

5.3.5 Broadcast Write Single Coil FAL PDU

5.3.5.1 Request primitive

Service identifier, function code = 5 (0x05); Unit ID = 0.

This function code is used to write a single coil to either ON or OFF in all the Unit ID addressable servers, by specifying Unit ID = 0.

This is an unconfirmed service.

The requested ON/OFF status is specified by a constant in the request data field. A value of 0xFF00 requests the output to be ON. A value of 0x0000 requests it to be OFF. All other values are illegal and do not affect the output.

The Request PDU specifies the address of the coil to be forced. Coils are addressed starting at zero. Therefore coil numbered 1 is addressed as 0.

The format is given in Table 11.

Table 11 – Broadcast write single coil request

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Allowed values: 0
Function code	Unsigned8	Service identifier, function code = 5 (0x05)
Address of coil	Unsigned16	Address of the coil. Allowed values: 0x0000 to 0xFFFF
Data single coil	Status flag	Single coil status value that has to be written. Allowed values: 0xFF00 or 0x0000

5.3.6 Broadcast Write Multiple Coils FAL PDU

5.3.6.1 Request primitive

Service identifier, function code = 15 (0x0F); Unit ID = 0.

This function code is used to force each coil in a sequence of coils to either ON or OFF in all the Unit ID addressable servers, by specifying Unit ID = 0.

This is an unconfirmed service.

The Request PDU specifies the coil references to be forced. Coils are addressed starting at zero. Therefore coil numbered 1 is addressed as 0.

The requested ON/OFF coils status is specified by the contents of the request data field. A logical '1' in a bit position of the field requests the corresponding output to be ON. A logical '0' requests it to be OFF.

The coils in the request message are packed as one input per bit of the data field. If the specified quantity of coils is not a multiple of eight, the remaining bits in the final data octet of data shall be padded with zeros (toward the high order end of the octet). The octet count field specifies the quantity of octets of data, n (including the padded octet, if any). The field data contains the n data octets, where n is the number in the field octet count.

The format is given in Table 12.

Table 12 – Broadcast write multiple coils request

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Allowed values: 0
Function code	Unsigned8	Service identifier, function code = 15 (0x0F)
Address of first coil	Unsigned16	Address of the first coil. Allowed values: 0x0000 to 0xFFFF
Quantity of coils	Unsigned16	Quantity of coils to be written. Allowed values: 1 to 1 968 (0x7B0), must be consistent with the Data octets count and the Data parameters
Data octets count	Unsigned16	Number of octets carrying the coil status values to be written. Allowed values: 1 to 246, must be consistent with the Quantity of coils and the Data parameters
Data	Status bit sequence	This parameter shall be used to specify the coil status values that have to be written. Allowed values: Must be consistent with the Quantity of coils and the Data octets count parameters

5.3.7 Read Input Registers FAL PDU

5.3.7.1 Request primitive

Service identifier, function code = 4 (0x04).

This function code is used to read from 1 to 125 input registers in a remote device. The Request PDU specifies the starting register address and the number of registers. In the PDU Registers are addressed starting at zero. Therefore input registers numbered 1 to 16 are addressed as 0 to 15.

The format is given in Table 13.

Table 13 – Read input registers request

Parameter name / field	Type	Description
Unit ID	Unsigned8	Address of the server. Allowed values: 1 to 247
Function code	Unsigned8	Service identifier, function code = 4 (0x04)
Address of input register to read	Unsigned16	Address of input register to read. Allowed values: 0x0000 to 0xFFFF
Quantity of input registers	Unsigned16	Quantity of input registers to read. Allowed values: 1 to 125 (0x7D)

5.3.7.2 Response primitive

The format is given in Table 14.