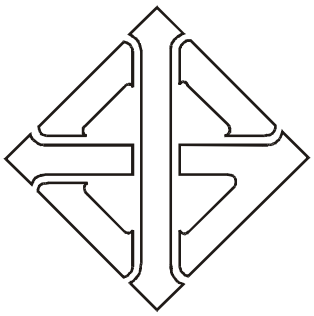

มาตรฐานผลิตภัณฑ์อุตสาหกรรม

THAI INDUSTRIAL STANDARD

มอก. 2267 เล่ม 3– 2549

IEC 62026–3(2000 –07)

ชุดประกอบอุปกรณ์ตัดต่อและชุดประกอบอุปกรณ์ควบคุมแรงดันต่ำ – การจัดประสานส่วนควบคุมกับกลอุปกรณ์ –

เล่ม 3 : การจัดประสานแบบ DeviceNet

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

CONTROLLER-DEVICE INTERFACES (CDIs) –

PART 3 : DEVICENET

สำนักงานมาตรฐานผลิตภัณฑ์อุตสาหกรรม

กระทรวงอุตสาหกรรม

ICS 29.130.20 ISBN 974-1509-54-5

มาตรฐานผลิตภัณฑ์อุตสาหกรรม

ชุดประกอบอุปกรณ์ตัดต่อและชุดประกอบอุปกรณ์ควบคุมแรงดันต่ำ – การจัดประสานส่วนควบคุมกับกลอุปกรณ์ –

เล่ม 3 : การจัดประสานแบบ DeviceNet

มอก. 2267 เล่ม 3–2549

สำนักงานมาตรฐานผลิตภัณฑ์อุตสาหกรรม
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เพื่อเป็นการส่งเสริมอุตสาหกรรม จึงกำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรมชุดประกอบอุปกรณ์ตัดต่อและชุดประกอบอุปกรณ์ควบคุมแรงดันต่ำ - การจัดประสานส่วนควบคุมกับกลอุปกรณ์ - เล่ม 3 : การจัดประสานแบบ DeviceNet ขึ้น

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้กำหนดขึ้นโดยรับ IEC 62026 - 3 (2000 - 07) LOW - VOLTAGE SWITCHGEAR AND CONTROLGEAR — CONTROLLER - DEVICE INTERFACES (CDIs) — Part 3 : DeviceNet มาใช้ในระดับเหมือนกันทุกประการ (Identical) โดยใช้ IEC ฉบับภาษาอังกฤษเป็นหลัก

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้กำหนดขึ้นเพื่อใช้ในการอ้างอิง และเพื่อให้ทันกับความต้องการของผู้ใช้มาตรฐาน ซึ่งจะได้แปลเป็นภาษาไทยในโอกาสอันควรต่อไป หากมีข้อสงสัยโปรดติดต่อสอบถามสำนักงานมาตรฐานผลิตภัณฑ์อุตสาหกรรม

คณะกรรมการมาตรฐานผลิตภัณฑ์อุตสาหกรรมได้พิจารณามาตรฐานนี้แล้ว เห็นสมควรเสนอรัฐมนตรีประกาศตามมาตรา 15 แห่งพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม พ.ศ. 2511

ประกาศกระทรวงอุตสาหกรรม

ฉบับที่ 3572 (พ.ศ. 2549)

ออกตามความในพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม

พ.ศ. 2511

เรื่อง กำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรม

ชุดประกอบอุปกรณ์ตัดต่อและชุดประกอบอุปกรณ์ควบคุมแรงดันต่ำ -

การจัดประสานส่วนควบคุมกับกลอุปกรณ์ -

เล่ม 3 : การจัดประสานแบบ DeviceNet

อาศัยอำนาจตามความในมาตรา 15 แห่งพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม พ.ศ.2511 รัฐมนตรีว่าการกระทรวงอุตสาหกรรมออกประกาศกำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรม ชุดประกอบอุปกรณ์ตัดต่อและชุดประกอบอุปกรณ์ควบคุมแรงดันต่ำ - การจัดประสานส่วนควบคุมกับกลอุปกรณ์ - เล่ม 3 : การจัดประสานแบบ DeviceNet มาตรฐานเลขที่ มอก. 2267 เล่ม 3-2549 ไว้ดังมีรายละเอียดต่อท้ายประกาศนี้

ประกาศ ณ วันที่ 6 พฤศจิกายน พ.ศ. 2549

โฆสิต ปั้นเปี่ยมรัษฎ์

รัฐมนตรีว่าการกระทรวงอุตสาหกรรม

มาตรฐานผลิตภัณฑ์อุตสาหกรรม
ชุดประกอบอุปกรณ์ตัดต่อและชุดประกอบอุปกรณ์ควบคุมแรงดันต่ำ – การจัดประสานส่วนควบคุมกับกลอุปกรณ์ –
เล่ม 3 : การจัดประสานแบบ DeviceNet

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้กำหนดขึ้นโดยรับ IEC 62026 - 3 (2000 - 07) LOW - VOLTAGE SWITCHGEAR AND CONTROLGEAR — CONTROLLER - DEVICE INTERFACES (CDIs) — Part 3 : DeviceNet มาใช้ในระดับเหมือนกันทุกประการ (Identical) โดยใช้ IEC ฉบับภาษาอังกฤษเป็นหลัก

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้ เหมาะสมที่จะใช้กับการจัดประสานอุปกรณ์วงจรควบคุมทั้งเดี่ยวหรือหมู่ เข้ากับตัวตัดต่อวงจรที่รับส่งข้อมูลและกำลังไฟฟ้าระหว่างกันด้วยสายเคเบิลเดี่ยวชนิด 2 ตัวนำซึ่งมีกำบังและตีเกลียวแกน

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้กำหนดคุณลักษณะที่ต้องการต่อซีดีไอรูปแบบนี้ ดังนี้

- การจัดประสานตัวควบคุมกับตัวตัดต่อวงจร
- การทำงานสภาวะปกติของอุปกรณ์
- โครงสร้างและการทำงาน
- การทดสอบแสดงความเป็นไปตามข้อกำหนดของคุณลักษณะที่ต้องการ

เพื่อใช้เป็นข้อกำหนดเพิ่มเติมเข้ากับที่ระบุไว้ใน มอก. 2267 เล่ม 1 - 2549 (IEC 62026-1 (2000-07))

รายละเอียดให้เป็นไปตาม IEC 62026 - 3 (2000 - 07)

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR – CONTROLLER-DEVICE INTERFACES (CDIs) –

Part 3: DeviceNet

1 Scope

This International Standard specifies an interface system between a single controller or multiple controllers, and control circuit devices or switching elements. The interface system uses two twisted shielded conductor pairs within one cable – one of these pairs provides a differential communication medium and the other pair provides power to the devices. This part establishes requirements for the interchangeability of components with such interfaces.

This standard specifies the following particular requirements for DeviceNet:

– requirements for interfaces between controllers and switching elements;
– normal service conditions for devices;
– constructional and performance requirements;
– tests to verify conformance to requirements.

These particular requirements apply in addition to the general requirements of IEC 62026-1.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 62026. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 62026 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

CISPR 11:1997, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP code)*

IEC 60947-1:1999, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-5-2:1997, *Low-voltage switchgear and controlgear – Part 5-2: Control circuit devices and switching elements – Proximity switches*

IEC 61000-4-2:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 2: Electrostatic discharge immunity test.* Basic EMC publication

IEC 61000-4-3:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 3: Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test.* Basic EMC publication

IEC 61000-4-5:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity tests*

IEC 61000-4-6:1996, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 6: Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61131-3:1993, *Programmable controllers – Part 3: Programming languages*

IEC 62026-1:2000, *Low-voltage switchgear and controlgear – Controller-device interfaces (CDIs) – Part 1: General rules*

ISO/IEC 7498-1:1994, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model*

ISO 11898:1993, *Road vehicles – Interchange of digital information – Controller area network (CAN) for high-speed communication*

ANSI/B93.55M-1981 (R1988), *Hydraulic Fluid Power – Solenoid Piloted Industrial Valves – Interface Dimensions for Electrical Connectors*

3 Definitions and abbreviations

For the purpose of this International Standard, the definitions given in IEC 62026-1 and the following definitions and abbreviations apply.

3.1
acknowledged fragmentation
fragmentation performed on an explicit message, in which the transmission of a fragment from the transmitting object is followed by the transmission of an acknowledgement by the receiving object. The reception of each fragment is acknowledged by the receiving object

3.2
ack status
field within an acknowledgement/response message format that indicates whether or not an error has been encountered by the receiver of a fragmented message. This applies specifically to the DeviceNet fragmentation protocol

3.3
application objects
set of object classes and their object instances that are available within the node. These objects manage and provide the exchange of data and messages across DeviceNet controller-device interfaces (CDIs) and within the DeviceNet compliant node

3.4
attribute
description of an externally accessible characteristic or feature of an object. Attributes typically provide status information or govern the operation of an object

3.5
bit-strobe
communication using strobing (see definition 3.13 of IEC 62026-1)

3.6
broadcast
communication from one node to all other nodes

3.7
CAN (Controller Area Network)
ISO specification that defines a generic physical layer and data link medium access procedure based on non-destructive bit-wise arbitration. See ISO 11898

3.8
CAN_H
positive half of the differential physical CAN signal

3.9
CAN_L
negative half of the differential physical CAN signal

3.10
client
a) object which uses the services of another (server) object to perform a task. See server (3.43)

b) initiator of a message to which a server reacts

3.11
common service
service used by DeviceNet objects (see annex A)

3.12
communication objects
objects that manage and provide run-time exchange of messages across DeviceNet

3.13
connection
logical binding between two or more application objects. These application objects may be located at the same node or at different nodes

3.14
connection ID (CID)
connection identifier assigned to all transmissions that are associated with a particular connection between multiple nodes

3.15
connection object
object that manages the communication-specific aspects associated with connections between nodes

3.16
consumer
end-point of a connection that is responsible for receiving data

3.17
destination MAC ID
MAC ID of a node that is to receive a message

3.18
device tap
physical point of attachment from a DeviceNet device to a trunk cable or a drop cable

3.19
device type
identification of a collection of device-dependent information describing a viable combination of options selected for all layers in the communication stack

3.20
dominant
one of two complementary logic levels on the physical signal. The dominant level is a logical "0"

3.21
duplicate MAC ID detection
DeviceNet-defined protocol that ensures no two nodes on the same link are assigned the same MAC ID

3.22
explicit messaging
message that commands the performance of a particular task and the return of the results of the task performance to the requester

3.23
fragmentation
DeviceNet protocol provided by the connection object that defines a method by which data greater than eight (8) bytes in length may be transmitted

3.24
group 2 client
Unconnected Message Manager (UCMM) capable device that has gained ownership of the predefined master/slave connection set within a server so that it may act as the client on those connections

3.25
group 2 only client
device that is acting as a group 2 client to a group 2 only server. The group 2 only client provides the UCMM functionality for group 2 only servers that are allocated to it

3.26
group 2 server
UCMM capable device that has been configured to act as the server for the predefined master/slave identifier connections

3.27
group 2 only server
slave device that is UCMM incapable and uses the predefined master/slave connection set to establish communications. A group 2 only device can transmit and receive only those identifiers defined by the predefined master/slave connection set

3.28
I/O connection
connection between a producer and one or more consumers for the purpose of exchanging application-specific, time-critical I/O data

3.29
I/O data
information which is transferred between I/O points and the controllers which use and set the values

3.30
I/O messaging
exchange of data in a previously defined format

3.31
isolated device
device in which some of the components are not referenced to the *U*– of the physical layer. See non-isolated device (3.36)

3.32
master
node which gathers and distributes I/Os using the predefined master/slave connection set

3.33
Medium Access Control (MAC) ID
link address of a DeviceNet node

3.34
multicast connection
logical connection from one object to multiple other objects. A multicast connection allows data to be transferred in a single transaction from a producer to multiple consumers sharing the same connection

3.35
node
DeviceNet entity which is identified at the data link level by a unique MAC ID

NOTE Multiple DeviceNet nodes may be implemented in one device but they appear as logically distinct nodes on the DeviceNet link.

3.36
non-isolated device
device in which all components are referenced to the *U*– of the physical layer. See isolated device (3.31)

3.37
object
a) abstract representation of a device's capabilities. Objects may be composed of any or all of the following components: 1) data (information which changes with time); 2) configuration (parameters for behaviour); 3) procedures (actions that may be performed using data and configuration)
b) collection of related data (in the form of variables) and procedures for operating on that data

3.38
point-to-point connection
connection that exists between two objects only. Explicit messaging connections are always point-to-point. I/O connections may be either point-to-point or multicast. See multicast connection (3.34)

3.39
predefined master/slave connection set
utilisation of an explicit messaging connection to create and configure connection objects within each connection end-point. Uses the general rules as a basis for the definition of a set of connections which facilitates communications typically seen in a master/slave relationship

3.40
producer
end-point of a connection that is responsible for sending data

3.41
recessive
one of two complementary logic levels on the physical signal. The recessive level is a logical "1"

3.42
serial number
unique 32-bit integer assigned by each manufacturer to every DeviceNet device. The number is stored within the device as an attribute of the identity object and is unique with respect to the manufacturer

3.43
server
object which provides services to another (client) object. See client (3.10)

3.44
service
operation or function that an object performs upon request from another object

3.45
slave
node that returns data to its master using the predefined master/slave connection set and a communication method set by the master

3.46
source MAC ID
MAC ID of a node that is transmitting a message

3.47
trigger
service used by an application to initiate the production of data

3.48
UCMM capable device
device that supports the UCMM (see 3.51)

3.49
UCMM incapable device
device that does not support the UCMM (see 3.51)

3.50
unconnected explicit message
explicit message between nodes that have not yet established a connection between each other

3.51
Unconnected Message Manager (UCMM)
function within a node that receives and processes unconnected explicit messages

3.52
Unsigned Short Integer (USINT)
8-bit integer

3.53
Unsigned Integer (UINT)
16-bit integer

4 Classification

4.1 General

DeviceNet interfaces controlling devices to control circuit devices or switching elements. DeviceNet uses two twisted shielded conductor pairs within one cable; one of these pairs provides a differential communication medium and the other pair provides power to the devices. The maximum current supported is 8 A at 24 V d.c. Data is transmitted at bit rates of 125 kbit/s, 250 kbit/s or 500 kbit/s with maximum cable lengths of 500 m, 250 m, and 100 m respectively. A maximum of eight bytes of data may be transmitted without fragmentation. A maximum of 64 nodes may be connected using a linear topology with a trunk line and drop lines (see figure 1). DeviceNet supports the transmission of I/O data, diagnostics, messaging and programming/configuration. Data exchange may be event-driven (change of state), cyclic, polled or multicast.

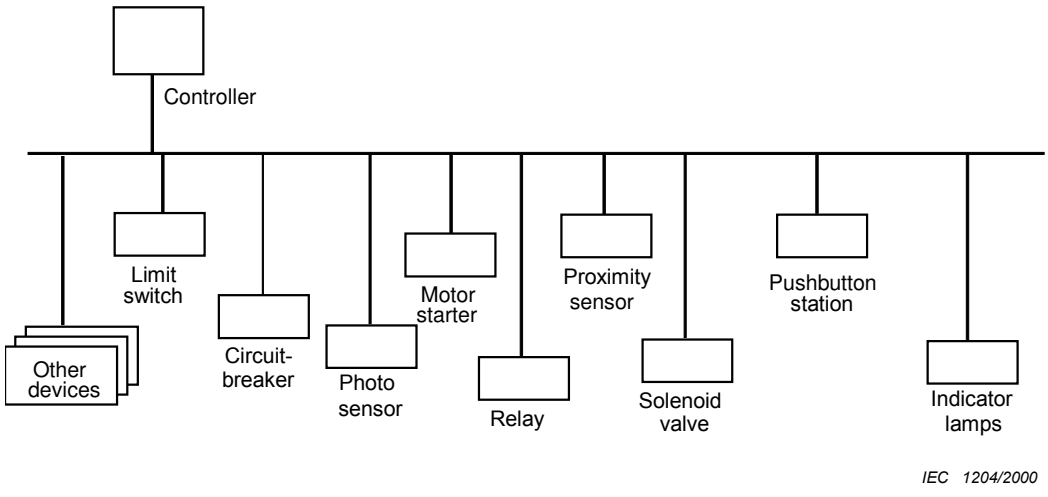

Figure 1 – Typical DeviceNet controller-device interfaces

This part of IEC 62026 defines a connection-based scheme to facilitate all application communications. A DeviceNet connection provides a communication path between multiple end-points. The end-points of a connection are applications that need to share data. Transmissions associated with a particular connection are assigned an identification value when a connection is established. This identification value is called connection ID (CID).

Connection objects model the communication characteristics of a particular application-to-application relationship.

The DeviceNet's connection-based scheme defines a dynamic means by which the following two types of connections may be established.

– **I/O connections**: provide dedicated, special purpose communication paths between a producing application and one or more consuming applications. Application-specific I/O data move through these paths.

  I/O messages are exchanged across I/O connections. An I/O message consists of a CID and associated I/O data. The connection end-points shall have knowledge of the intended use or meaning of the I/O message.

  This part of IEC 62026 does not define any particular use for I/O messaging. There are a wide variety of functions that may be accomplished using I/O messaging. The meaning and/or intended use of all I/O messages shall be made known to the system either by the particular type of product transmitting an I/O message, or based upon the configuration performed using explicit messaging.

– **Explicit messaging connections:** provide generic, multi-purpose communication paths between two devices. Explicit messages provide the typical request/response-oriented communications.

  Explicit messages are exchanged across explicit messaging connections. Explicit messages are used to command the performance of a particular task and to report the results of performing the task.

  DeviceNet defines an explicit messaging protocol that states the meaning of the message. An explicit message consists of a CID and associated messaging protocol information.

The rules that govern the dynamic establishment of these connections are used as a foundation upon which a predefined set of connections is defined.

4.2 DeviceNet communication model

The abstract object-oriented communication model of a DeviceNet node includes the following:

– **unconnected message manager (UCMM):** processes DeviceNet unconnected explicit messages;

– **identity object:** identifies and provides general information about the device;

– **connection class:** allocates and manages internal resources associated with both I/O and explicit messaging connections;

– **connection object:** manages the communication specific aspects associated with a particular application-to-application relationship;

– **DeviceNet object:** provides the configuration and status of a physical DeviceNet CDI;

– **message router:** forwards explicit request messages to the appropriate object;

– **application objects:** implement the intended purpose of the product.

4.3 DeviceNet and CAN

DeviceNet is based on ISO 11898 and uses the Controller Area Network (CAN) technology.

The relationships between DeviceNet, CAN and the OSI reference model (ISO/IEC 7498-1) are shown in figure 2.

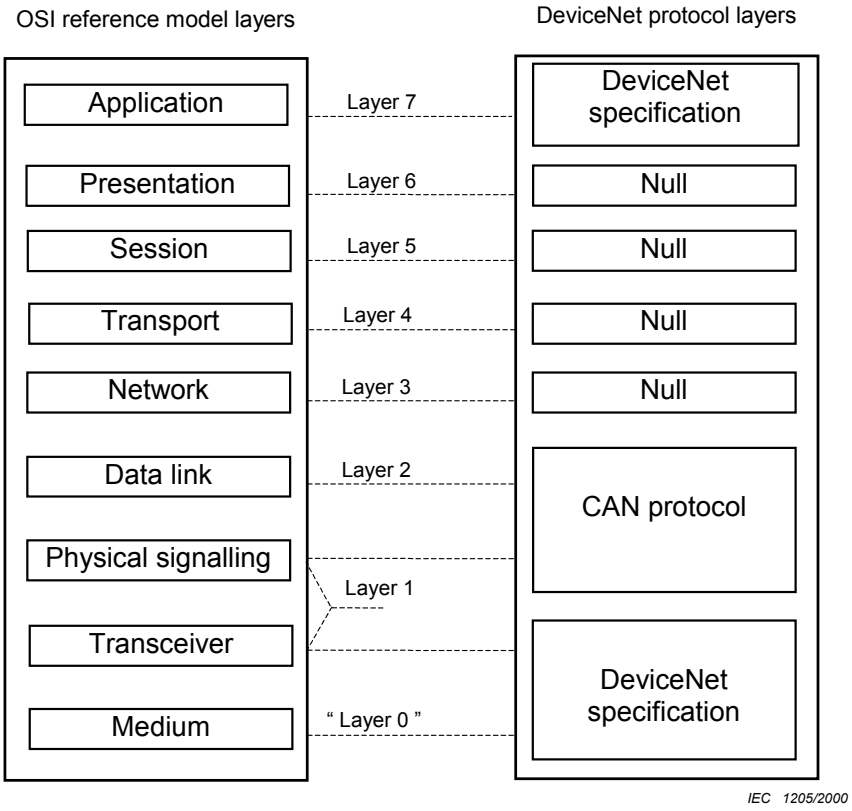

Figure 2 – DeviceNet protocol architecture compared with the OSI reference model

5 Characteristics

5.1 DeviceNet connections

5.1.1 General

DeviceNet is a connection-based controller-device interface. DeviceNet connections are used to provide logical paths between multiple applications. When a connection is established, the transmissions associated with that connection are assigned a connection ID (CID). If the connection involves a bi-directional exchange, then two CID values shall be assigned to the connection.

DeviceNet uses the CAN identifier field and defines the steps involved in the dynamic establishment of I/O and explicit messaging connections.

5.1.2 DeviceNet's use of the CAN identifier field

NOTE DeviceNet uses the 11 bit CAN identifier field ("Standard frame format") as described in ISO 11898.

The 11 CAN identifier bits available within DeviceNet are subdivided into four separate message groups: group 1, group 2, group 3 and group 4.

For connection-based messages, the CID is placed within the CAN identifier field. Figure 3 also describes the components of a DeviceNet CID.

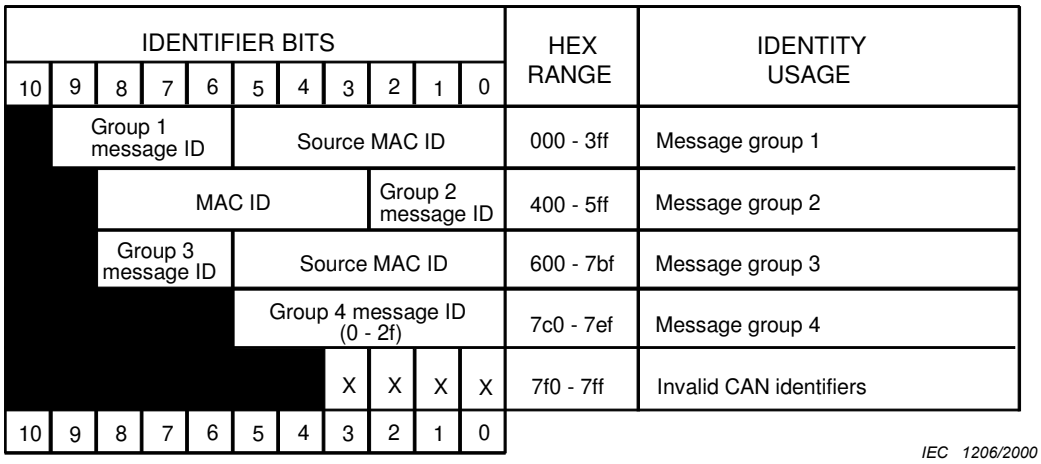

Figure 3 – DeviceNet's use of the CAN identifier field

As shown in figure 3, the CAN identifier field on DeviceNet contains the following:

– **message ID:** identifies a message within a message group inside a particular node. When a connection is established, the nodes utilise a message ID in combination with a MAC ID to generate a CID. The resulting CID is specified in the CAN identifier field associated with related transmissions;

– **source MAC ID:** groups 1 and 3 require the specification of a source MAC ID within the CAN identifier field;

– **MAC ID:** message group 2 allows the specification of either the source or the destination within the MAC ID portion of the CAN identifier field.

Both explicit messaging and I/O connections may be established in message groups 1, 2 and 3.

Group 2 message ID values 6 and 7 are used as follows:

– group 2 message ID 6 is used for the configuration of the communications utilised in a master/slave application (see 5.5);

– group 2 message ID 7 is used in the detection of nodes that have been assigned identical MAC IDs (see 5.4).

Group 3 message ID values 5, 6 and 7 are used as follows:

– group 3 message ID 5 is used when sending responses associated with unconnected explicit messaging requests;

– group 3 message ID 6 is used when sending unconnected explicit messaging requests;

– group 3 message ID 7 is invalid and shall not be used.

Group 4 is reserved for future use.

5.1.3 Connection establishment

5.1.3.1 Explicit messaging connections and UCMM

Message group 3 defines the identifier codings to support unconnected explicit messaging. Unconnected explicit messages establish and manage explicit messaging connections. Unconnected request messages are specified by transmitting a group 3 message whose message ID component is set to 6. The only valid services that can be transmitted as unconnected explicit request messages are:

– open explicit messaging connection request;
– close connection request.

Responses to unconnected explicit requests are transmitted as unconnected response messages. Unconnected response messages are specified by transmitting a group 3 message whose message ID component is set to 5. The only valid services that can be transmitted as unconnected explicit response messages are:

– open explicit messaging connection response;
– close connection response;
– error response.

5.1.3.2 I/O connections

I/O connections are dynamically established by interfacing with the connection class across a previously established explicit messaging connection. A connection instance shall be created and configured at each node.

5.2 DeviceNet messaging protocol

5.2.1 Explicit messaging

5.2.1.1 General

This subclause describes the explicit messaging protocol and presents details associated with the dynamic establishment of explicit messaging connections (see figure 4).

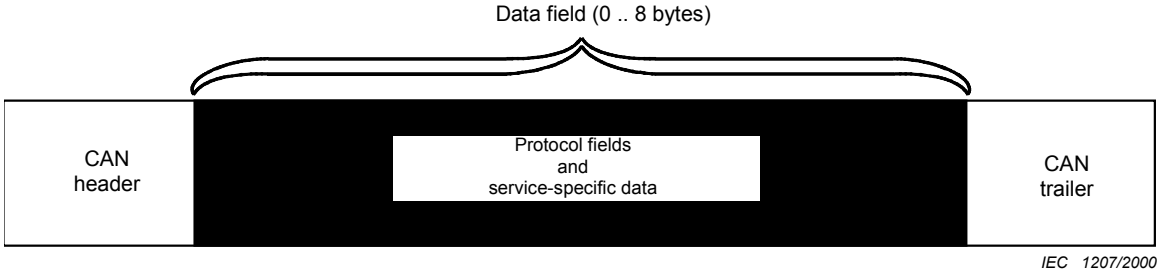

Figure 4 – Explicit message CAN data field use

Figure 5 provides the format of the CAN data field associated with explicit messages.

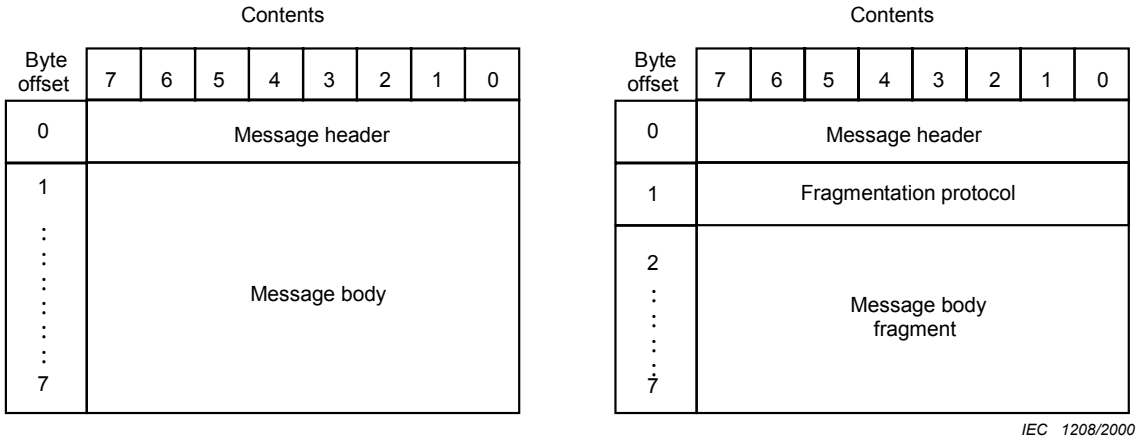

Figure 5 – Explicit message data field format

The data field of a transmission that contains the complete explicit message includes:

– a message header;

– the entire message body.

If the explicit message is greater than eight bytes in length, it shall be transmitted in a fragmented manner. The fragmentation/re-assembly function is provided by the connection object. A piece of a fragmented explicit message includes:

– a message header;

– the fragmentation protocol (see 5.2.3.2);

– a message body fragment.

5.2.1.2 Message header

The message header is located within byte offset zero in the CAN data field of an explicit message and shall be formatted as shown in figure 6.

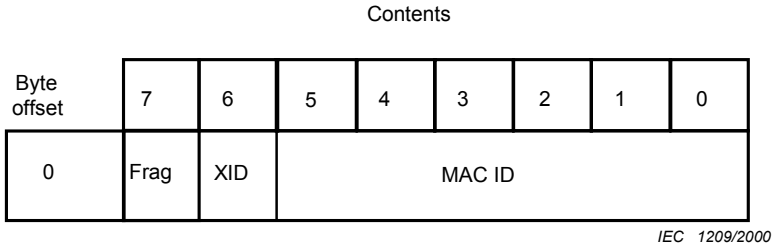

Figure 6 – Explicit message header format

Message header contents:

– **frag** (fragment bit): indicates whether or not this transmission is a piece of a fragmented explicit message:

0 = non-fragmented

1 = fragmented

– **XID (transaction ID):** this field is utilised by an application to match a response with the associated request. This field is simply echoed by the server in a response message. The server module does not utilise this field to perform any type of duplicate message detection logic;

– **MAC ID:** contains either the source or destination MAC ID.

When an explicit message is received, the MAC ID field within the message header is examined. If the destination MAC ID is specified in the CID, then the source MAC ID of the other end-point shall be specified in the message header. If the source MAC ID is specified in the CID, then the receiving module's MAC ID shall be specified in the message header. If neither of these conditions are true, then the message shall be discarded.

5.2.1.3 Message body

The message body contains a service field and service-specific arguments.

The first argument specified within the message body is the service field, which identifies the particular request or response being delivered. Figure 7 illustrates the format of the service field.

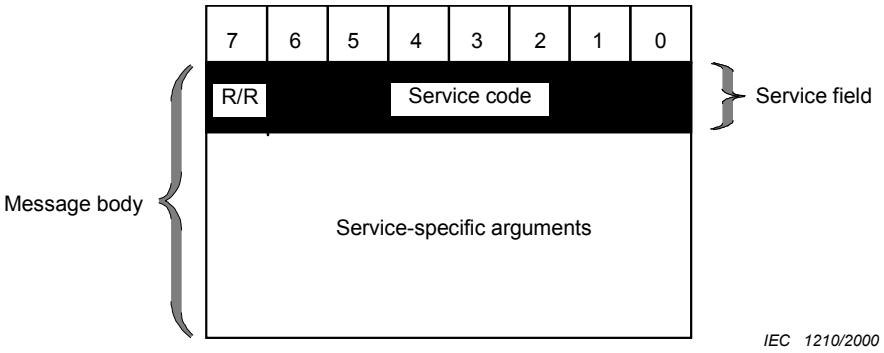

Figure 7 – Service field format

Service field contents:

– **service code:** the value specified within the least significant seven bits of the service field byte that indicates the type of service being transmitted;

– **R/R:** the most significant bit in the service field. Its value determines whether a message is a request or a response:

0 = request

1 = response

DeviceNet defines a set of common services. DeviceNet common services are the open set whose parameters and required behaviours are defined in this standard (see annex A).

The information following the service field is specific to the particular type of service being transmitted.

5.2.1.4 Fragmentation protocol

If the transmission is a piece of a fragmented explicit message, then the data field contains the message header, the fragmentation protocol and a message body fragment. The fragmentation protocol facilitates the fragmentation and reassembly of explicit messages which have a message body greater than eight bytes (see 5.2.3).

5.2.1.5 UCMM services

5.2.1.5.1 General

The Unconnected Message Manager (UCMM) provides for the dynamic establishment of explicit messaging connections. This subclause presents a detailed description of the service specific arguments associated with the open and close explicit messaging connection services provided by the UCMM. See 9.3.3 for the test specifications regarding the establishment of explicit messaging connections.

The UCMM processes two services which manage the allocation and deallocation of explicit messaging connections:

– **open explicit messaging connection:** service code = $4B_{hex}$. Used to establish an explicit messaging connection;

– **close connection:** service code = $4C_{hex}$. Used to delete a connection object and deallocate all associated resources.

These services are accessed using the unconnected explicit request and response CAN identifier fields shown in figure 3. When processing an unconnected explicit request, the UCMM may need to return an error indication to the requestor and, as such, the error response explicit message may be transmitted with the unconnected explicit response CAN identifier.

5.2.1.5.2 Open explicit messaging connection request

This service requests the establishment of a logical connection between two nodes across which explicit messages will be transmitted. This service is transmitted as an unconnected request message (message group 3, message ID 6) (see figure 8).

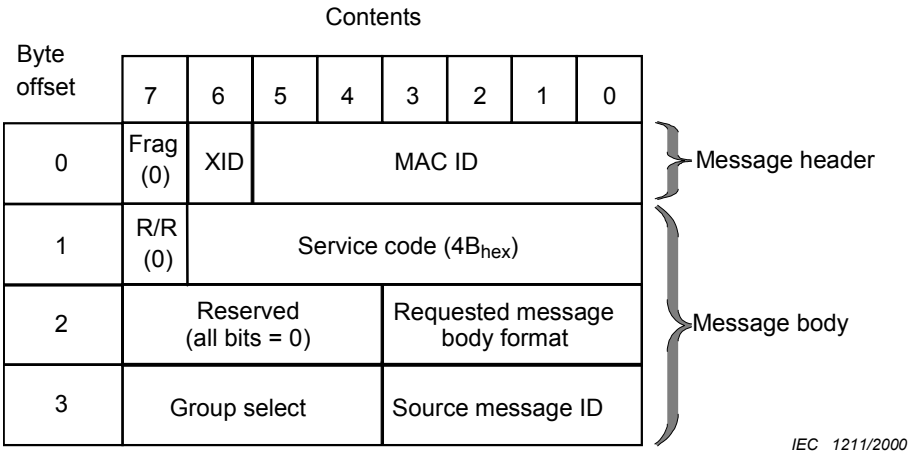

Figure 8 – Open explicit messaging connection request format

Open explicit messaging connection request contents:

– **frag (0)/transaction ID/MAC ID**: see 5.2.1.2. The destination MAC ID is always specified in the message header associated with an open explicit messaging connection request/response;

– **R/R bit (0):** indicates this is a request message;

– **service code ($4B_{hex}$):** identifies this message as an open explicit messaging connection service;

– **reserved bits:** these shall be set to zero by the transmitter;

– **requested message body format:** the field used by the client to request a particular message body format for subsequent explicit messages transmitted over this connection.

The server node responding to this open explicit messaging request defines the message body format to be used over this connection. See table 1 for message body format values. Servers shall do one of the following:

– refuse the request and return the appropriate format value in the open explicit messaging connection response;

– accept this request by echoing the same format value in the open explicit messaging connection response;

Table 1 – Message body format values

Value	Meaning
0	DeviceNet (8/8). Class = 8-bit integer, instance ID = 8-bit integer 1)
1	DeviceNet (8/16). Class = 8-bit integer, instance ID = 16-bit integer 2)
2	DeviceNet (16/16). Class = 16-bit integer, instance ID = 16-bit integer 3)
3	DeviceNet (16/8). Class = 16-bit integer, instance ID = 8-bit integer 4)
4 – F_{hex}	Reserved
NOTE Messages transmitted across this connection are formatted as described in 5.2.1.6.	
1) The class and instance ID fields are specified as 8-bit integers (USINT). 2) The class ID is specified as an 8-bit integer (USINT) and the instance ID is specified as a 16-bit integer (UINT). 3) The class and instance ID fields are specified as 16-bit integers (UINT). 4) The class ID is specified as a 16-bit integer (UINT) and the instance ID is specified as an 8-bit integer (USINT).	

– **group select:** the field that indicates the message group across which messages associated with this connection are to be exchanged. The group select values are shown in table 2;

Table 2 – Group select values

Value	Meaning
0	Message group 1
1	Message group 2 1)
2	Reserved
3	Message group 3
4 – F_{hex}	Reserved
1) The message group 2 identifier allows for specification of either the source or destination MAC ID. For explicit messaging connections established across message group 2, the client places the MAC ID of the server in the connection ID when transmitting messages across this connection. The server places its own MAC ID in the connection ID when transmitting messages across this connection. This process requires the server to allocate two separate message IDs from its group 2 pool.	

The client selects the message group across which the transmissions associated with this explicit messaging connection will take place. If the server cannot satisfy the request, then it shall reject the request and return an error response;

– **source message ID:** the use of this field depends on the value within the group select field (see table 3):

Table 3 – Source message ID in open explicit messaging connection request

If group select equals:	Then the source message ID:
0 or 3	Specifies the message ID the client has allocated from its group 1 or 3 message ID pool. The client shall use this message ID in combination with its own MAC ID to generate the connection ID specified when it transmits a message across this connection [1)]
1	Is ignored/set to the value zero (0) [2)]

[1)] The client places this value within the message ID component of the message group 1 or 3 Identifier.

[2)] Explicit messaging connections established across message group 2 require the server to allocate two group 2 message IDs and return them in the open explicit messaging connection response message. The client shall use one of these message IDs to generate the connection ID it specifies when transmitting a message across this connection. The other shall be used by the server to generate the connection ID it specifies when transmitting a message across this connection.

The UCMM within the server validates the open explicit messaging connection request arguments. If they are valid, the UCMM invokes the create service of the connection class to obtain a connection object instance (see 5.3.2.6). The resulting connection object is automatically configured to be an explicit messaging connection object.

If the server supports multiple message body formats and the client has requested one of those formats, then the server echoes the requested message body format in the open explicit response message. If the server does not support multiple message body formats, then the server specifies its default format in the open explicit messaging connection response.

If no errors are detected, then an open explicit messaging connection success response is returned. If an error is detected, then an error response message is returned.

5.2.1.5.3 Open explicit messaging connection success response

This service is used to respond to a successful open explicit messaging connection request message (see figure 9).

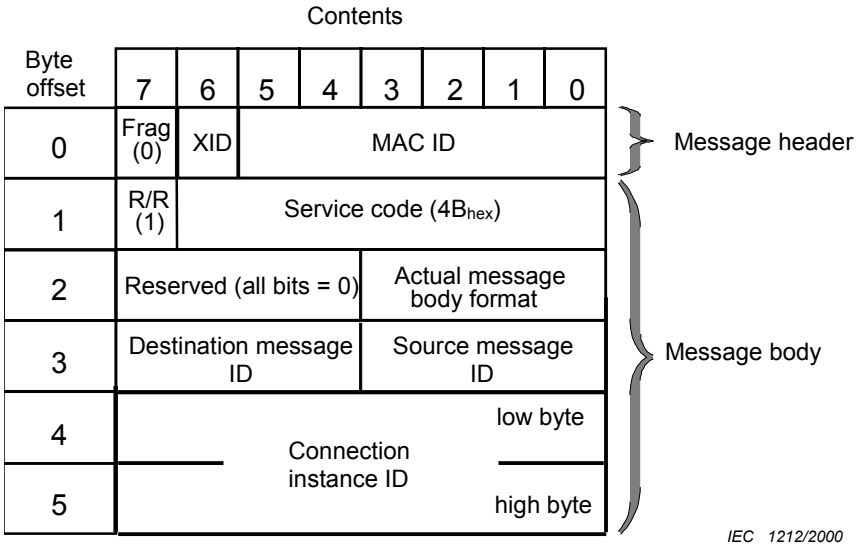

Figure 9 – Open explicit messaging connection response format

Open explicit messaging connection response contents:

- **frag (0)/transaction ID/MAC ID:** see 5.2.1.2. The destination MAC ID is always specified in the message header associated with an open explicit messaging connection request/response;
- **R/R bit (1):** indicates that this is a response message;
- **service code ($4B_{hex}$):** identifies this message as an open explicit messaging connection service;
- **reserved bits:** these shall be set to zero by the transmitter;
- **actual message body format:** the field used by the server to define the format of the message body associated with subsequent explicit messages transmitted over this connection (as described in table 1);
- **destination message ID:** the use of this field depends on the message group across which the connection takes place (as described in table 4);

Table 4 – Destination message ID in an open explicit messaging connection response

If group select within the open request was set to:	Then the destination message ID in the open response:
0 or 3	Is ignored and shall be set to the value zero (0)
1	Is used by the client in combination with the server's MAC ID to generate the connection ID it specifies when transmitting across this connection

- **source message ID:** the message ID value that the server has allocated. The server allocates a message ID from its group 1, 2, or 3 message ID pool that is used in conjunction with its own MAC ID (source MAC ID) to generate the connection ID that is specified when it transmits a message across this connection;
- **connection instance ID:** the server creates an explicit messaging connection object when it successfully services an open request. This field holds the instance ID value (16-bit integer field) assigned to that explicit messaging connection object.

5.2.1.5.4 Close connection request

This service is used to terminate a connection (either I/O or messaging) within one of the end points. The reception of the close connection request message by the UCMM results in the invocation of the connection class's delete service (see 5.3.2.6). A close connection request message is transmitted as an unconnected request message.

The responder verifies that the specified connection instance exists. If the connection instance exists and can be deleted, then it is deleted. All resources associated with the connection instance are freed. If the request is successfully serviced, then a close connection response is returned. If the request is not successful, an error response is returned.

Close connection request contents (see figure 10):

– **frag (0)/transaction ID/MAC ID:** see 5.2.1.2;
– **R/R bit (0):** indicates that this is a request message;
– **service code ($4C_{hex}$):** identifies that this is a close connection service;
– **connection instance ID:** the field that specifies the connection instance to be deleted. The format for the connection instance ID within this message is always specified as a 16-bit integer.

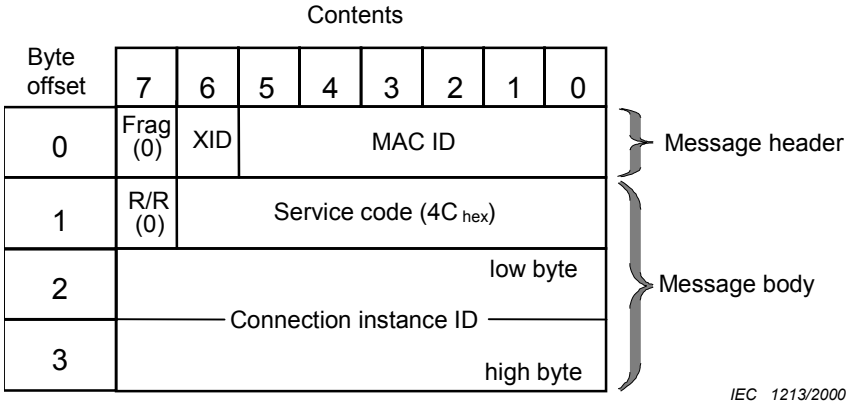

Figure 10 – Close connection request format

5.2.1.5.5 Close connection response

This service is used to respond to a successful close connection request message.

Close connection response format contents (see figure 11):

– **frag (0)/transaction ID/MAC ID:** see 5.2.1.2;
– **R/R bit (1):** indicates that this is a response message;
– **service code ($4C_{hex}$):** identifies this message as a close connection service.

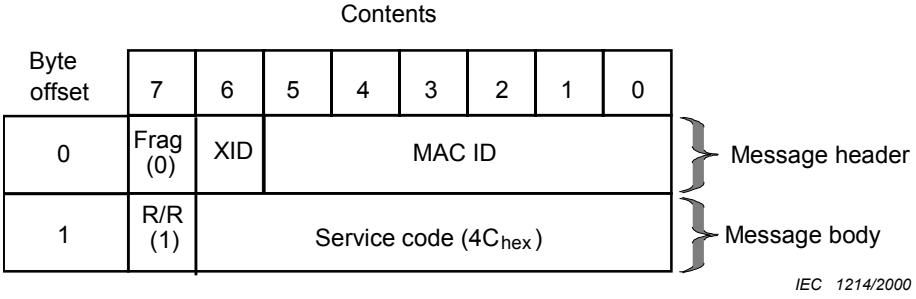

Figure 11 – Close connection response format

5.2.1.5.6 Error response

Table 5 shows a standard set of UCMM related error conditions and the error code (both general error code and additional error code) information to be used in an associated error response message. The format of an error response message is described in 5.2.1.7.

Table 5 – UCMM error conditions/codes

Error condition	General error name	General error code (hex)	Additional error code (hex)
Service code not open or close	Service not supported	08	FF
Group select resource error	Resource unavailable	02	01
Group select out of range	Invalid parameter	20	01
No server connections available	Resource unavailable	02	02
No server message IDs available	Resource unavailable	02	03
Client source message ID invalid	Invalid parameter	20	02
Duplicate client source message ID	Resource unavailable	02	04
Connection instance ID invalid	Object does not exist	16	FF

Error condition description:

– **service not open or close:** a service received across the UCMM port is not of type open or close and is therefore not supported by UCMM;

– **group select resource error:** the group select argument indicates utilising a message group which is not supported by the device;

– **group select out of range:** the group select field contains an invalid value;

– **no server connections available:** the maximum number of connections supported by this server has already been reached;

– **no server message IDs available:** the server has allocated all message IDs within the message group requested by the client;

– **client source message ID invalid:** the source message ID received with an open explicit message connection request is invalid for the specified message group;

– **duplicate client source message ID:** the source message ID and source MAC ID received within an open explicit messaging connection request are already in use for a group 1 or group 3 explicit messaging connection;

– **connection instance ID invalid:** the connection instance ID received with the close connection request does not exist.

5.2.1.6 Connection-based explicit messaging

A connection-based explicit message is a message transmitted over an explicit messaging connection. A connection-based explicit message shall conform to the formats described in this subclause.

Figure 12 shows the format for the message associated with a non-fragmented explicit request.

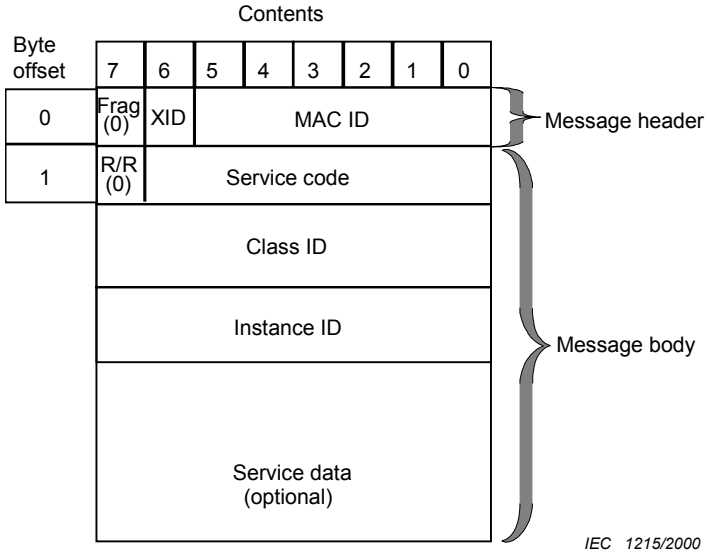

Figure 12 – Non-fragmented explicit request message format

Non-fragmented explicit request message contents:

– **frag (0)/transaction ID/MAC ID:** see 5.2.1.2;

– **R/R bit (0):** indicates that this is a request message;

– **service code:** defines the service being requested;

– **class ID:** defines the object class towards which this request is directed. The class ID is specified within either an 8- or 16-bit integer field based on the actual message body format value returned in the open explicit messaging connection response;

– **instance ID:** defines the particular instance within the object class towards which this request is directed. The instance ID is specified within either an 8- or 16-bit integer field based on the actual message body format value returned in the open explicit messaging connection response. DeviceNet uses the value zero to denote that the request is directed towards the class itself rather than a specific instance within the class;

– **service data:** carries request-specific data. Formats for the DeviceNet common services are described in annex A. Class-specific and object-specific service definitions include the format of this field.

Figure 13 shows the format for the message associated with a non-fragmented success response:

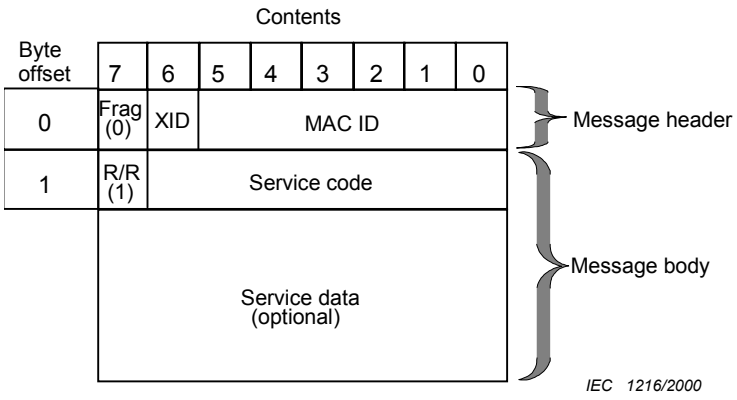

Figure 13 – Non-fragmented success response message format

Non-fragmented success response message contents:

– **frag (0)/transaction ID/MAC ID:** see 5.2.1.2;
– **R/R bit (1):** indicates that this is a response message;
– **service code:** contains the service code sent in the request message;
– **service data:** carries request-specific data.

5.2.1.7 Error response message

The error response message is returned when an error is encountered while attempting to service a previously received explicit request message. The error response may be sent as either a connection-based (request was received across an explicit messaging connection) or unconnected (request was an unconnected explicit request message) response message. Figure 14 shows the format of an error response message.

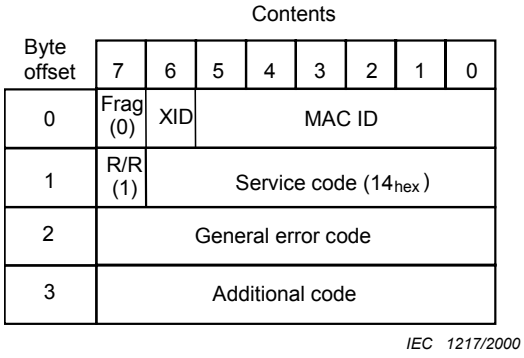

Figure 14 – Error response message

Error response message contents:

– **frag (0)/transaction ID/MAC ID:** see 5.2.1.2;
– **R/R bit (1):** indicates that this is a response message;
– **service code (14_{hex}):** identifies this message as an error response;
– **general error code:** identifies the encountered error. See annex B for a list of general error codes;
– **additional code:** contains an object-specific or service-specific value that further describes the error condition. If the responding object has no additional information to specify, then the value FF_{hex} is placed within this field.

5.2.2 Input/output messaging

DeviceNet defines a fragmentation protocol for transfer of an I/O message greater than eight bytes in length. This is the only protocol information carried within the data field of an I/O message (see figure 15).

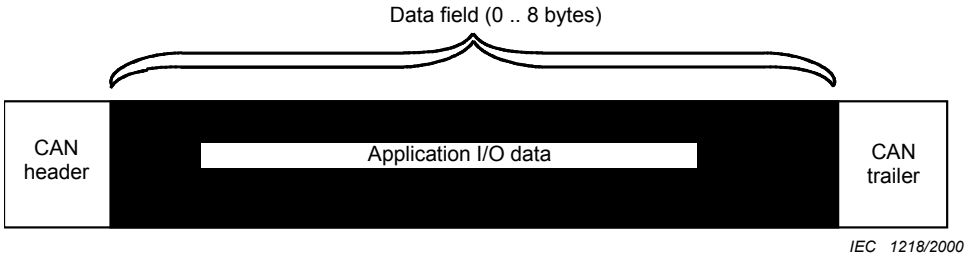

Figure 15 – Data field of an I/O message

5.2.3 Fragmentation/reassembly

5.2.3.1 General

This subclause defines the means by which a message whose length is greater than eight bytes is fragmented and reassembled. The fragmentation/reassembly function is provided by the DeviceNet connection object.

The logic that triggers a fragmented transmission is:

– explicit messaging connection object instances examine the length of each message to be transmitted. If the message is greater than eight bytes in length, then the fragmentation protocol is used;

– I/O connection object instances examine the produced_connection_size attribute of the connection object (see 5.3.2). If the produced_connection_size attribute is greater than eight, then the fragmentation protocol is used.

Two types of fragmentation are defined:

– **acknowledged:** performed when fragmenting an explicit message;

– **unacknowledged:** performed when fragmenting an I/O message.

5.2.3.2 Fragmentation protocol

The fragmentation protocol is located within a single byte in the CAN data field and is formatted as shown in figure 16.

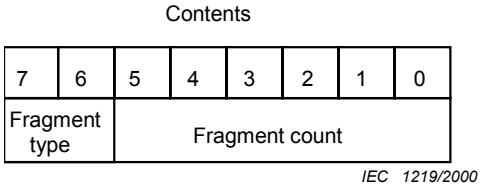

Figure 16 – Format of DeviceNet fragmentation protocol

Fragmentation protocol contents:

– **fragment type:** indicates whether this is the first fragment, one of the middle fragments or the last fragment (see table 6);

Table 6 – Fragment type bit values

Value	Meaning
0	First fragment. The fragment count field shall contain the value 0 or 3F [1)]
1	Middle fragment [2)]
2	Last fragment [3)]
3	Fragment acknowledgement [4)]

[1)] If the fragment count contains the value zero (0), then this is the first in a series of fragments. If the fragment count field contains the value 3F, then this is also the last transmission in the series.

[2)] This fragment is neither the first nor the last fragment in the series.

[3)] Marks this as the last fragment.

[4)] The value the receiver of a fragmented message uses to acknowledge the reception of a fragment.

– **fragment count:** marks each separate fragment such that the receiver may determine whether or not a fragment has been missed. If the fragment type is the first fragment, then this field takes on a special meaning (as described in table 6). The fragment count is increased by one for each successive fragment in a series and resets to zero at overflow (fragmentcount = (fragmentcount + 1) mod 64).

For I/O message fragmentation, the fragmentation protocol information is placed within byte offset 0 (see figure 17).

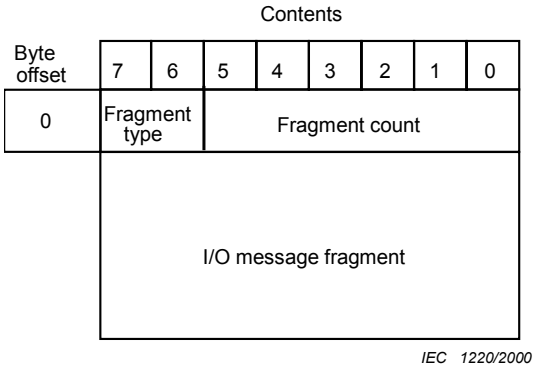

Figure 17 – I/O message fragment format

For explicit message fragmentation, the fragmentation protocol information is placed within byte offset 1 (see figure 18).

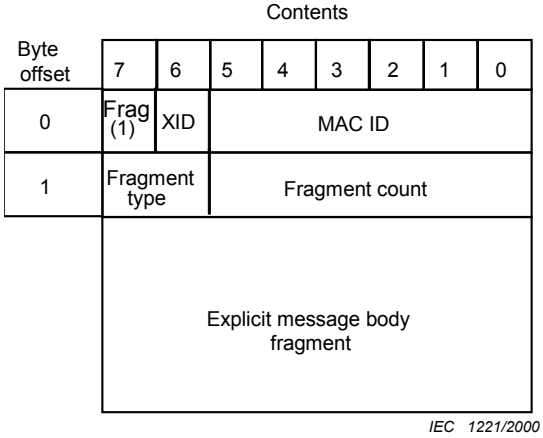

Figure 18 – Explicit message fragment format

The frag bit within the message header in figure 18 is set to 1 to indicate that this is a piece of the explicit message, not the entire message. The value 1 here also indicates that the next byte contains the fragmentation protocol.

The receiver of a fragmented series of transmissions parses the fragmented message as defined in this subclause. This procedure applies to both I/O and explicit message fragmentation.

If the first transmission is expected by the connection and the fragment type is equal to the first fragment:

– if the fragment count is $3F_{hex}$, then this is the only transmission in the series, and the connection processes the message and awaits the beginning of a new series;
– if the fragment count is 0, then this is the first in a series of transmissions and the connection stores the fragment and saves the fragment count.

If the first transmission is expected by the connection and either the fragment type is not equal to the first fragment or the fragment count is not equal to 0 or $3F_{hex}$, the connection discards the transmission and awaits the beginning of a new message.

If the first transmission is not expected by the connection, then the connection verifies:

– that the fragment type is not the first fragment, and
– that the fragment count is numerically one (1) greater than the previous value received.

If one of these checks fails, then an error has been detected. If both checks pass, then the fragment is appended to the previously received fragment(s), and the fragment type is parsed to determine whether or not more fragments are to be expected.

If more fragments are forthcoming, then the connection saves the received fragment count and waits for the next fragment. If this is the last transmission in the series and an error has not been detected, then the connection processes the message and resets to looking for the beginning of a new series.

If an explicit message is being fragmented, then the receiver shall generate and transmit an acknowledgement after the reception of each fragment.

If an error is detected, then an error recovery specific to whether this is a fragmented I/O or explicit message takes place.

If the detection of a missed fragment was triggered by the reception of the first fragment in the next series, then any processing associated with the current series is immediately discontinued, the fragments stored in memory are discarded and processing immediately begins on the new series.

5.2.3.3 Unacknowledged fragmentation

The fragmentation of an I/O message is performed in an unacknowledged fashion. Unacknowledged fragmentation consists of the back-to-back transmission of the fragments from the transmitting module. The receiving module(s) returns no acknowledgements.

When an I/O connection's send_message service is invoked, it examines its connection_size attribute to determine whether or not a fragmented series of messages is to be transmitted. If the connection_size attribute is greater than eight (8), then the fragmentation protocol is placed within the I/O.

If the connection_size attribute is less than or equal to eight (8) bytes, then the raw data is transmitted without the presence of the fragmentation protocol.

If the application requests to transmit a piece of data whose length is greater than the connection_size attribute, then an internal error is indicated and the transmission does not occur. If the receiving I/O connection object detects a missed fragment by determining that the received fragment count is not equal to the previously received fragment count plus one (1), then the following error recovery steps are taken:

– all subsequent fragments in this series are dropped and the application is not informed of an I/O message reception;
– the connection object begins looking for the beginning of a new fragmented series of transmissions and discards the remaining fragments in this series.

5.2.3.4 Acknowledged fragmentation

Acknowledged fragmentation is used for fragmented explicit messages. Acknowledged fragmentation consists of the transmission of a fragment from the transmitting node followed by the transmission of an acknowledgement by the receiving node. The receiving node acknowledges the reception of each fragment.

Figure 19 shows the format for the acknowledgement message transmitted by the receiver after each explicit message fragment is received.

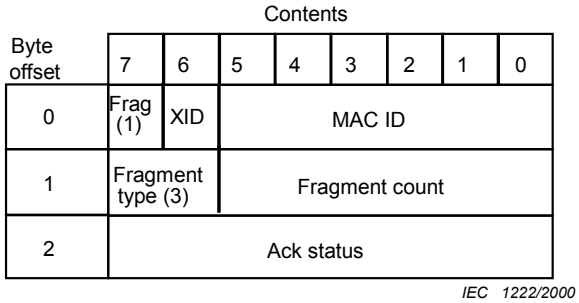

Figure 19 – Acknowledgement message format

Acknowledgement message contents:

– **fragment type:** indicates that this is a fragment acknowledgement by placing the value 3 within this field;

– **fragment count:** echoes the last fragment count value received;

– **ack status:** indicates whether or not an error has been detected by the receiver of the fragmented message. The ack status bit values are defined in table 7.

Table 7 – Ack status bit values

Value	Meaning
0	Success. No errors have been detected and the fragmented transmission shall continue
1	Too much data. The maximum amount of data the receiver can receive across this connection has been exceeded
2 – 255	Reserved

The transmitting node functions as specified below:

– the connection object formulates the message header by setting the frag bit to one (1), the XID (transaction ID) field to the value specified by the application, and initialises the MAC ID field in the same manner it would a non-fragmented explicit message. The message headers associated with each separate fragment are identical;

– the connection object then places the appropriate fragmentation protocol information into the message. The connection object stores the fragment count that was inserted into the message;

– the connection object then takes the next piece of the message body and places it into the message;

– the message is transmitted and a wait for the acknowledgement timer is started. The amount of time to wait is application-specific;

– if the wait for the acknowledgement timer expires, then the connection object automatically retries the last transmission. The connection object retries once. If the timer expires once again (two consecutive wait for acknowledgement time-outs), then the application is informed that an error has been detected and the requested transmission cannot take place;

– if an acknowledgement is received, then the connection object determines whether or not the fragment count in the acknowledgement is equal to the last fragment count it transmitted. If they are equal, then the fragment was successfully delivered and acknowledged, and normal processing continues. If the values are not equal, then the connection object continues to wait for an acknowledgement with a matching fragment count.

The initial state associated with the receiving module entails waiting for either the first fragment in a fragmented transmission or for the reception of a complete explicit message. The receiving side functions as specified below:

– if the message header indicates that this is a fragmented portion of an explicit message, then the connection object examines the fragmentation protocol to determine its validity. If the connection has yet to receive the first transmission in the series (in the initial state) and the fragment type field is not equal to the first fragment, then the fragment is dropped and no acknowledgement is returned;
– if the fragment type indicates that this is the first fragment, then the fragment count shall equal zero (0). If this is the case, then the message fragment is stored and an acknowledgement is returned. If the fragment type indicates first fragment and the fragment count is not zero (0), then the fragment is dropped and no acknowledgement is returned;
– if the fragment count is one (1) greater than the previously received count and the fragment type does not indicate that this is the first fragment, then the next fragment has been received. The fragment is appended to the previously received fragment(s) and an acknowledgement is returned. The fragment count associated with this fragment is stored;
– if the fragment count is neither one (1) greater nor equal to the previously received count, then the fragment is discarded and no acknowledgement is returned. The receiver resets to the initial state;
– when the final fragment is received and the acknowledgement is transmitted, the connection object continues processing the message as if it were non-fragmented.

5.2.4 Duplicate MAC ID detection protocol

Each DeviceNet node shall be assigned a MAC ID and is required to participate in the duplicate MAC ID detection algorithm, as defined in 5.4.

A special message ID value is defined within group 2 to identify the duplicate MAC ID check message (see figure 20).

IDENTIFIER BITS											MESSAGE ID MEANING
10	9	8	7	6	5	4	3	2	1	0	
1	0	MAC ID						Group 2 message ID			Group 2 messages
1	0	Destination MAC ID						1	1	1	Duplicate MAC ID check message

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Figure 20 – Duplicate MAC ID check CAN identifier field

The data field associated with the duplicate MAC ID check message has the format shown in figure 21.

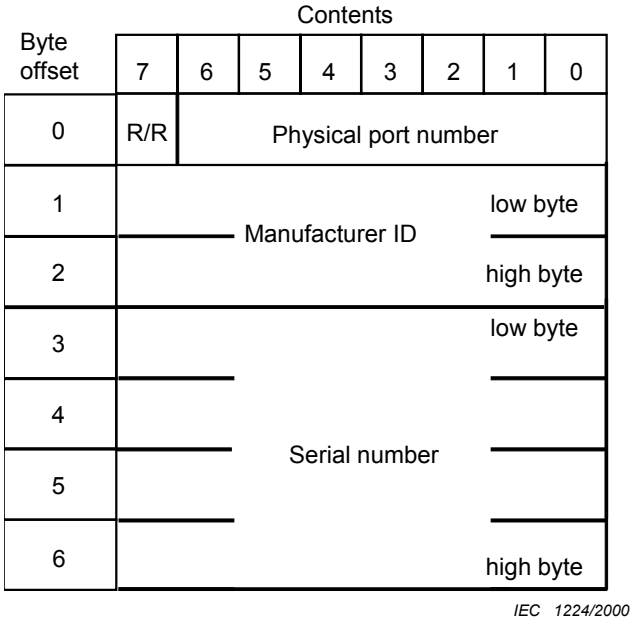


Figure 21 – Duplicate MAC ID check message data field format

Duplicate MAC ID check message data field contents:

– **R/R bit:** request/response bit. The value in this field indicates whether this is a duplicate MAC ID check request or a response message:

  0 = request

  1 = response

– **physical port number:** an identification value internally assigned to each physical DeviceNet port of a device. Devices that have a single port shall place the value zero (0) within this field;

– **manufacturer ID:** a 16-bit integer field (UINT) containing the identification code assigned to the manufacturer of the device that is transmitting the message;

– **serial number:** see 3.42.

5.3 DeviceNet communication object classes

5.3.1 General

The DeviceNet communication objects manage and provide the exchange of messages. The services, attributes and behaviours associated with the main communication objects are detailed in this subclause. See annex D for a description of DeviceNet data type specification and encoding, and annex E for the definition of auxiliary communication objects.

5.3.2 Connection object class definition (class ID code: 5)

5.3.2.1 General

The connection class allocates and manages the internal resources associated with both I/O and explicit messaging connections. The specific instance generated by the connection class is referred to as a connection instance or a connection object.

5.3.2.2 Connection object class attribute

The connection class attribute is defined in table 8.

Table 8 – Connection class attribute

Attribute ID	Need in implementation	Access rule	Attribute name	Data type	Attribute description
1	Optional	Get	Revision	UINT	Revision of the connection class definition upon which the implementation is based

The attribute shall be set to 1.

All other attributes are reserved.

5.3.2.3 Connection object class services

The connection class supports the following DeviceNet common services (as described in table 9).

Table 9 – Connection class services

Need in implementation	Service name	Service description
Optional	Create	Creates a connection object
Optional	Delete	Deletes all connection objects and releases all associated resources. When the delete service is sent to the connection class, all instances are deleted
Optional	Reset	Resets all resettable connection objects. The conditions under which a connection is resettable are listed in the state-event matrix in table 20
Optional	Find_next_ object_instance	Searches for instance IDs associated with existing connection objects
[1)]	Get_attribute_ single	Reads a connection class attribute value
[1)] Get_attribute_single is required if the connection class attribute is supported.		

5.3.2.4 Connection object instance attributes

Table 10 shows the connection instance attributes and their associated data types.

Table 10 – Connection object instance attributes

Attribute ID (decimal)	Need in implementation	Attribute name	Data type	Brief description of attribute
1	Required	state	USINT	State of the object
2	Required	instance_type	USINT	Indicates either I/O or messaging connection
3	Required	transportclass_trigger	BYTE	Defines behaviour of the connection
4	Required	produced_connection_id	UINT	Placed in CAN identifier field when the connection transmits
5	Required	consumed_connection_id	UINT	CAN identifier field value that denotes message to be received
6	Required	initial_comm_ characteristics	BYTE	Defines the message group(s) across which productions and consumptions associated with this connection occur
7	Required	produced_connection_ size	UINT	Maximum number of bytes transmitted across this connection
8	Required	consumed_connection_ size	UINT	Maximum number of bytes received across this connection
9	Required	expected_packet_rate	UINT	Defines timing associated with this connection
10 – 11				Reserved
12	Required	watchdog_timeout_action	USINT	Defines how to handle inactivity/watchdog time-outs
13	Required	produced_connection_ path_length	UINT	Number of bytes in the produced_connection_path attribute
14	Required	produced_connection_path	Array of USINT	Specifies the application object(s) whose data is to be produced by this connection object
15	Required	consumed_connection_ path_length	UINT	Number of bytes in the consumed_connection_path attribute
16	Required	consumed_connection_ path	Array of USINT	Specifies the application object(s) that are to receive the data consumed by this connection object
17	Required	production_inhibit_time	UINT	Defines minimum time between new data production

The list below provides detailed descriptions of the DeviceNet connection object instance attributes. The defined default attribute values shall be used when no other internal and/or system-defined rules exist.

1) **state:** Defines the current state of the connection instance. Table 11 defines the possible states and assigns a value used to indicate that state.

Table 11 – Values assigned to the state attribute

Value	State name	Description
0	Non-existent	No connection exists
1	Configuring	The connection has been created and is waiting: (a) to be configured and (b) to be instructed to apply the configuration
2	Waiting for connection ID	The connection instance is waiting for its consumed_connection_id and/or produced_connection_id attribute to be set [1)]
3	Established	The connection has been configured and the configuration has been applied
4	Timed-out	If a connection object experiences an inactivity/watchdog time-out, then a transition shall be made to this state. See the watchdog_timeout_action attribute description (table 17) and the description of the inactivity/watchdog timer (5.3.2.5.3) for more details
5-255	Reserved	

[1)] When the connection instance attributes are applied, it may not be possible for the node to generate the produced_connection_id and/or consumed_connection_id values (see initial_comm_characteristics attribute in table 15 for rules). If this is the case, then all the tasks required to apply the attributes are performed except for the initialisation of these attributes within the connection and associated link producer/consumer objects, and the connection instance assumes the Waiting for connection ID state

All resources associated with a connection instance that has been dynamically created across an explicit messaging connection shall be released if the explicit messaging connection breaks down before the dynamically created connection instance has transitioned to the established state.

When a transition is made to the established state, all timers associated with the connection object shall be activated (see 5.3.2.5).

2) **instance_type:** Defines the instance type (as described in table 12).

Table 12 – Values assigned to the instance_type attribute

Value	Meaning
0	Explicit messaging
1	I/O
2-255	Reserved

3) **transportclass_trigger:** Identifies whether this is a producing only, consuming only, or both producing and consuming connection. If this end-point is to perform a data production, this attribute also identifies the event that triggers the production. The eight bits are divided as follows (see figure 22).

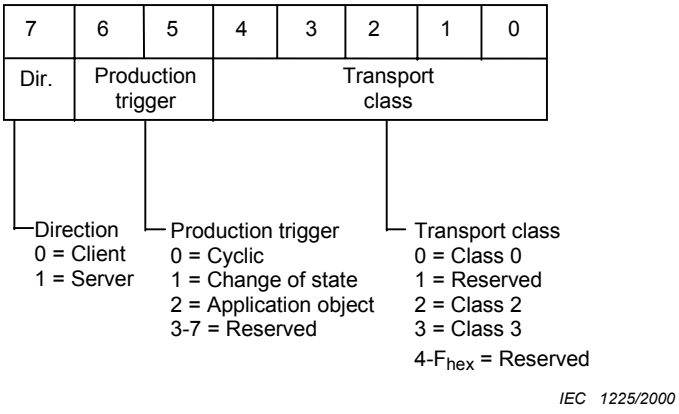


Figure 22 – Transportclass_trigger

4) **produced_connection_id:** contains the CID to be associated with transmissions sent across this connection (if any). This value shall be specified in the CAN identifier field when this connection transmits (see 5.1.2).

Table 13 – Values defined for the produced_connection_id attribute

Value	Meaning
0 – $7F0_{hex}$	The value to be placed in the CAN identifier field when this connection transmits
$7F1_{hex}$ – $FFFE_{hex}$	Reserved
$FFFF_{hex}$	Default value assigned to this attribute within an I/O connection. This attribute shall retain this value if this connection instance is not producing any data (consumer only)

5) **consumed_connection_id:** Contains the CID which identifies messages to be received across this connection (if any). This is the CAN identifier field value that is used with messages to be received by this connection object (see 5.1.2). The following values are defined (see table 14).

Table 14 – Values defined for the consumed_connection_id attribute

Value	Meaning
0 – $7F0_{hex}$	The value that identifies messages to be consumed by this connection object instance. This shall be specified in the CAN identifier field of messages that are to be consumed
$7F1_{hex}$ – $FFFE_{hex}$	Reserved
$FFFF_{hex}$	Default value assigned to this attribute within an I/O connection. This attribute shall retain this value if this connection instance is not consuming any data (producer only)

6) **initial_comm_characteristics:** Defines the message group(s) across which this connection produces and consumes. This byte is divided into two nibbles (see figure 23).

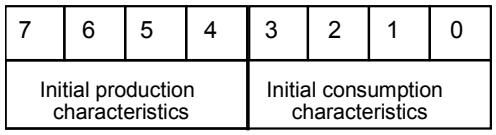


Figure 23 – Initial_comm_characteristics attribute format

Table 15 lists the values that are possible within the initial production characteristics nibble (upper nibble) of the initial_comm_characteristics attribute.

Table 15 – Values for the initial production characteristics nibble

Value	Meaning
0	Produce across message group 1 [1)]
1	Produce across message group 2 (destination) [2)]
2	Produce across message group 2 (source) [3)]
3	Produce across message group 3 [4)]
4 – E_{hex}	Reserved
F_{hex}	Default value [5)]

1) The producing node generates the CID value and loads it into the connection object's produced_connection_id attribute. The producing node allocates a message ID from its group 1 message_ID pool and combines this with its source MAC ID to generate the CID. The numerically lowest available group 1 message ID shall be used in generating the produced_connection_id attribute value. This value shall also be loaded into the corresponding consumed_connection_id attribute associated with the consuming connection object(s).

2) The destination MAC ID shall be placed within the MAC ID component of the group 2 identifier field. In this case, the consuming node generates the CID value to be associated with transmissions across this connection. When the consuming node has generated this value and loaded it into the appropriate connection object's consumed_connection_id attribute, this value shall be read and subsequently loaded into the producing connection object's produced_connection_id attribute.

3) The source MAC ID shall be placed within the MAC ID component of the group 2 identifier. In this case, the producing node generates the CID value and loads it into the connection object's produced_connection_id attribute. The numerically lowest available group 2 message ID shall be used in generating the produced_connection_id attribute value. This value shall also be loaded into the corresponding consumed_connection_id attribute associated with the consuming connection object(s).

4) The producing node generates the CID value and loads it into the connection object's produced_connection_id attribute. The producing node allocates a message ID from its group 3 message ID pool and combines this with its source MAC ID to generate the CID. The numerically lowest available group 3 message ID shall be used in generating the produced_connection_id attribute value. This value shall also be loaded into the corresponding consumed_connection_id attribute associated with the consuming connection object(s).

5) The default value assigned to the initial production characteristics nibble within an I/O connection. If this is a consuming only I/O connection, then the default value remains in this nibble. Explicit messaging connection objects automatically configure this attribute when the connection is established.

Table 16 lists the possible values within the initial consumption characteristics nibble (lower nibble) of the initial_comm_characteristics attribute.

Table 16 – Values for the initial consumption characteristics nibble

Value	Meaning
0	Consume a group 1 message [1)]
1	Consume a group 2 message (destination) [2)]
2	Consume a group 2 message (source) [3)]
3	Consume a group 3 message [4)]
4 – E_{hex}	Reserved by DeviceNet
F_{hex}	Default value [5)]

1) The producing node generates the CID value. This value shall be loaded into the consumed_connection_id attribute associated with the consuming connection object(s).

2) The destination MAC ID is specified within the group 2 identifier. The consuming node generates the CID value and loads it into the consumed_connection_id attribute associated with this connection object. The numerically lowest available group 2 message ID shall be used in generating the consumed_connection_id attribute value. This value shall be loaded into the producing connection object's produced_connection_id attribute.

3) The source MAC ID is specified within the group 2 identifier. In this case, the producing node generates the CID value and loads it into the connection object's produced_connection_id attribute. This value shall be loaded into the consumed_connection_id attribute associated with the consuming connection object(s).

4) The producing node generates the CID value. The CID value shall be loaded into this connection object's consumed_connection_id attribute.

5) The default value assigned to the initial consumption characteristics nibble within an I/O connection. If this is a producing only I/O connection, then the default value remains in this nibble. Explicit messaging connections automatically configure this attribute when the connection is established.

The node that generates a CID shall guarantee that it does not allocate the message ID/MAC ID pair in such a way that two separate nodes are capable of transmitting identical bit patterns within the identifier field (see 5.3.2.9).

7) **produced_connection_size:** The meaning of this attribute is different for explicit messaging connections and for I/O connections.

For explicit messaging connections:

This attribute defines the maximum number of message body bytes that a node is able to transmit across this connection.

Nodes that do not support the transmission of the fragmentation protocol initialise this attribute to the value 7 (message header (1 byte) + message body (7 bytes) = 8 bytes, which is the maximum length of a non-fragmented explicit message). Nodes that cannot or do not predefine a transmit length limit place the value $FFFF_{hex}$ into this attribute. Nodes that support the fragmentation protocol, but place a limit on the amount of message body bytes that can be transmitted in a single fragmented series initialise this attribute with this limit.

For I/O connections:

If the transportclass_trigger attribute identifies that this connection instance is a producer, then this attribute identifies the maximum amount of I/O data that may be produced as a single message across this connection. The amount of I/O data to be transmitted shall be less than or equal to the produced_connection_size attribute.

This attribute defaults to 0 within an I/O connection. If this attribute is set to a value greater than 8 in an I/O connection, then the connection shall use the fragmentation protocol.

I/O messages that contain no application I/O data and were configured to contain data indicate a no data event for the receiving application object(s). The behaviour of an application object upon detection of the no data event is application object-specific.

8) **consumed_connection_size:** The meaning of this attribute is different for explicit messaging connections and for I/O connections.

For explicit messaging connections:

This attribute defines the maximum number of message body bytes that this node is able to receive across this connection.

Nodes that do not support the reception of the fragmentation protocol initialise this attribute to the value 7 (message header (1 byte) + message body (7 bytes) = 8 bytes, which is the maximum length of a non-fragmented explicit message). Nodes that cannot or do not predefine a receive length limit place the value $FFFF_{hex}$ into this attribute. Nodes that support the fragmentation protocol, but place a limit on the amount of message body bytes that can be received in a single fragmented series initialise this attribute with this limit.

For I/O connections:

If the transportclass_trigger attribute identifies that this connection instance is a consumer, then this attribute identifies the maximum amount of data that may be received as a single message across this connection. The amount of I/O data received shall be less than or equal to the consumed_connection_size attribute. If an I/O connection object receives a message whose length is greater than the length specified by this attribute value, then it discards the message and discontinues any subsequent processing.

This attribute defaults to 0 within an I/O connection. If this attribute is set to a value greater than 8 in an I/O connection**,** then the connection shall use the fragmentation protocol.

9) **expected_packet_rate:** This attribute is used to generate the values loaded into the transmission trigger timer and the inactivity/watchdog timer. This attribute determines the value(s) loaded into the timers in milliseconds. See 5.3.2.5 for a description of the transmission trigger and inactivity/watchdog timers.

A request to configure this attribute may result in the specification of a time value that a product cannot meet. When a request to modify this attribute is received, the following steps shall be performed:

– if the specified value is not equal to a multiple of the available clock resolution, then the value is rounded up to the next useable value. This useable value is loaded into the expected_packet_rate attribute and is reported in the service data field of a set_attribute_single response message;

– if the requested value is equal to an increment of the clock resolution, then the requested value is loaded into the expected_packet_rate attribute and is reported in the service data field of a set_attribute_single response message.

The following steps shall be performed by a connection object in the established state when a request to modify the expected_packet_rate attribute is received:

– the current transmission trigger timer and inactivity/watchdog timer are cancelled;

– a new transmission trigger timer and a new inactivity/watchdog timer are activated based on the new value in the expected_packet_rate attribute.

This attribute defaults to 2 500 (2 500 ms) within explicit messaging connections and to zero (0 ms) within an I/O connection.

10) Reserved.

11) Reserved.

12) **watchdog_timeout_action:** This attribute defines the action the connection object shall perform when the inactivity/watchdog timer expires (see table 17);

Table 17 – Values for the watchdog_timeout_action

Value	Meaning
0	Transition to timed-out state. The connection transitions to the timed-out state and remains in this state until it is reset or deleted. This is the default value for this attribute in the case of I/O connections
1	Auto delete. The connection class automatically deletes the connection in the event of an inactivity/watchdog time-out. This is the non-modifiable value for this attribute in the case of explicit messaging connections
2	Auto reset. The connection remains in the established state and restarts the inactivity/watchdog timer
3 – 255	Reserved

13) **produced_connection_path_length:** Identifies the number of bytes of information within the produced_connection_path attribute. This is set when the produced_connection_path attribute is set. This attribute defaults to the value 0.

14) **produced_connection_path:** The produced_connection_path attribute is made up of a byte stream which defines the application object(s) whose data is to be produced by this connection object. The format of this byte stream is specified in annex C. This attribute defaults to non-existent upon creation of the connection. It remains non-existent within explicit messaging connections and within connection objects that do not produce.

15) **consumed_connection_path_length:** Identifies the number of bytes of information within the consumed_connection_path attribute. This is set when the consumed_ connection_path attribute is set. This attribute defaults to the value 0.

16) **consumed_connection_path:** The consumed_connection_path attribute is made up of a byte stream which defines the application object(s) that are to receive the data consumed by this connection object. The format of this byte stream is specified in annex C. This attribute defaults to non-existent upon creation of the connection. It remains non-existent within explicit messaging connections and within connection objects that do not consume.

17) **production_inhibit_time:** This attribute is used to configure the minimum time between successive data production. This attribute determines the value loaded into the timer in milliseconds. A value of 0 (the default value for this attribute) indicates no inhibit time.

    A request to configure this attribute may result in the specification of a time value that a product cannot meet. When a request to modify this attribute is received, the following steps shall be performed:

    – if the specified value is not equal to a multiple of the available clock resolution, then the value is rounded up to the next useable value. This useable value is loaded into the production_inhibit_time attribute and is reported in the service data field of a set_attribute_single response message;

    – if the requested value is equal to an increment of the clock resolution, then the requested value is loaded into the production_inhibit_time attribute and is reported in the service data field of a set_attribute_single response message.

The production_inhibit_time value is loaded into the production inhibit timer each time new data production occurs.

When a connection object is in the established state, any modification to the production_ inhibit_time attribute has no effect on a currently running production inhibit timer. The new production_inhibit_time value is loaded into the production inhibit timer when the next data production occurs.

When the apply_attributes service is received, production_inhibit_time shall be verified against the expected_packet_rate attribute. If the expected_packet_rate value is greater than zero, but less than the production_inhibit_time value, then an error shall be returned. The additional error code returned to the apply_attributes service is 11_{hex}, indicating the production_inhibit_time attribute.

5.3.2.5 Connection timing

5.3.2.5.1 General

Three types of timers are involved in a connection:

– transmission trigger timer;

– inactivity/watchdog timer;

– production inhibit timer.

5.3.2.5.2 Transmission trigger timer

Expiry of the transmission trigger time is an indication that the associated connection object may need to transmit a message. If a production has not occurred since the timer was activated, then the connection object shall produce, in order to avoid an inactivity/watchdog time-out at the server end-point(s).

5.3.2.5.3 Inactivity/watchdog timer

This timer is used by consuming connection objects including:

– client end-point connection objects whose transportclass_trigger attribute indicates either transport class 2 or 3;

– all server end-point connection objects.

This timer is activated when the connection transitions to the established state. The tasks listed below shall be performed by a connection object upon detecting that a valid message has been consumed:

– the current inactivity/watchdog timer shall be stopped;

– a new inactivity/watchdog timer shall be activated.

These actions shall take place before the received message is processed.

Expiry of the inactivity/watchdog time is an indication that the connection object has timed-out while waiting to consume. The connection object shall then perform the following steps:

– issue an indication of this event to the application;

– perform the action indicated by the watchdog_timeout_action attribute.

The initial value loaded into the inactivity/watchdog timer is either 10 000 ms or expected_ packet_rate multiplied by 4, depending on which value is numerically the greater. All subsequent activations of the inactivity/watchdog timer use expected_packet_rate multiplied by 4 as the number of milliseconds to load into the inactivity/watchdog timer. If the expected_packet_rate attribute contains the value 0, then the inactivity/watchdog timer is neither activated nor used by the connection object.

5.3.2.5.4 Production inhibit timer

This timer shall be managed by the connection object within the client end-point of a connection when the production_inhibit_time attribute value is non-zero. This timer is started when data is produced by the application object. The connection object shall not produce new data if this timer is running, although a retry may be sent. Expiry of the production inhibit time allows the connection object to send new data.

The production inhibit timer is initialised with the value in the production_inhibit_time attribute. If the production_inhibit_time attribute contains the value 0, then the production inhibit timer is neither activated nor used by the client end-point.

5.3.2.6 Connection object instance services

The connection object instance supports the following DeviceNet common services (as described in table 18).

Table 18 – Connection object instance services

Need in implementation	Service name	Service description
Required	Get_attribute_ single	Reads a connection object attribute
Optional	Set_attribute_ single	Modifies a connection object attribute. The connection object returns information in the service data field of a set_attribute_single response when the expected_packet_rate attribute is modified as indicated in 5.3.2.4
Optional	Reset	Resets the inactivity/watchdog timer associated with a connection object. When a connection in the timed-out state receives a reset request, it also transitions back to the established state
Optional	Delete	Deletes a connection object and releases all associated resources
Optional	Apply_attributes	Delivers the connection object to the application which performs the set of tasks necessary to create the specified connection. A connection instance returns the produced_connection_id and consumed_connection_id attributes within the service data field of an apply_attributes response message, as indicated in table 19
NOTE Service codes are defined in annex A.		

The information to be specified by a connection object instance within the service data field of a successful apply_attributes response is shown in table 19.

Table 19 – Service data for connection object apply_attributes response

Name	Data type	Description of parameter
Produced CID	UINT	Contains the value within the connection instance's produced_connection_id attribute
Consumed CID	UINT	Contains the value within the connection instance's consumed_connection_id attribute

The connection object also supports the following internal services:

– **send_message:** used internally to trigger the transmission of a message;

– **receive_data:** used internally to deliver a received frame to the connection object. The connection object determines whether or not it needs to reassemble a series of data fragments into a complete message before processing the message.

5.3.2.7 Connection instance behaviour

Figure 24 provides a general overview of the behaviour associated with an I/O connection object (instance_type attribute = I/O).

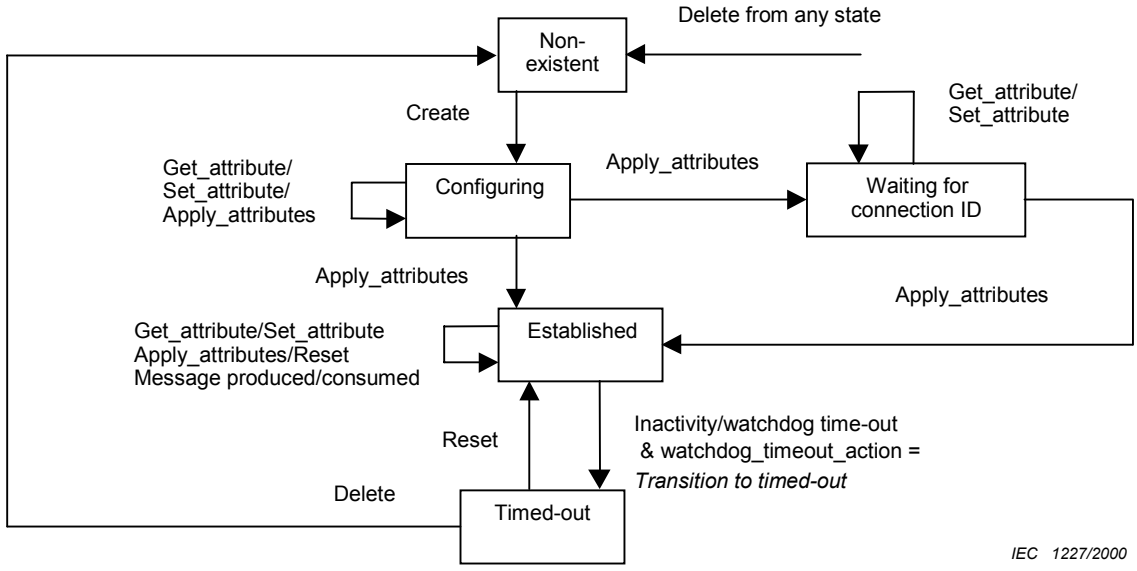


Figure 24 – I/O connection object state transition diagram

Table 20 provides a detailed state-event matrix for an I/O connection.

Table 20 – I/O connection state-event matrix

I/O connection object state					
Event	**Non-existent**	**Configuring**	**Waiting for CID**	**Established**	**Timed-out**
Connection class receives a create request	Class creates a connection object. Set instance_type to I/O. Set other attributes to default values. Transition to configuring	Not applicable	Not applicable	Not applicable	Not applicable
Connection class receives a delete request	Error: object does not exist (general error code 16_{hex})	Release all associated resources Transition to non-existent	Release all associated resources Transition to non-existent	Release all associated resources Transition to non-existent	Release all associated resources Transition to non-existent
Set_attribute_ single	Error: object does not exist (general error code 16_{hex})	Validate/service the request according to 5.3.2.8 Return response	If request to modify produced_ or consumed_ connection_id, then validate the value, service the request and return response If this is a request to access any other attribute, then return an error response whose general error code is set to $0C_{hex}$	Validate/service the request according to 5.3.2.8 Return response	Validate/service the request according to 5.3.2.8 Return response

Table 20 *(continued)*

I/O connection object state					
Event	**Non-existent**	**Configuring**	**Waiting for CID**	**Established**	**Timed-out**
Get_attribute_ single	Error: object does not exist (general error code 16_{hex})	Validate/service the request according to 5.3.2.8 Return response	Validate/service the request according to 5.3.2.8 Return response	Validate/service the request according to 5.3.2.8 Return response	Validate/service the request according to 5.3.2.8 Return response
Reset	Error: object does not exist (general error code 16_{hex})	Error: the object cannot perform the requested service in its current mode/state (general error code value = $0C_{hex}$)	Error: the object cannot perform the requested service in its current mode/state (general error code value = $0C_{hex}$)	If the inactivity/ watchdog timer is running, cancel it and re-start using the value in the expected_ packet_rate attribute	Using the value in the expected_ packet_rate attribute, start the inactivity/watch-dog timer (if the expected_packet_ rate attribute has not been set to zero) and transition back to the established state
Apply_attributes	Error: object does not exist (general error code 16_{hex})	Deliver connection object to the application which validates the attribute information. If either of the connection_id attributes (produced or consumed) needs to be configured and cannot be generated by this node, then perform the other steps necessary to configure the connection, return a success response and transition to the waiting for CID state. If all attributes are configured, then perform the steps necessary to satisfy this connection, start all required timers, and transition to the established state. If an error is detected, then an error response is returned and the connection remains in the configuring state [1)]	If either of the connection_id attributes (produced or consumed) still needs to be configured and cannot be generated by this node, then return a success response and remain in the waiting for CID state. If the produced_ and/or consumed_ connection_id attributes are configured, transition to the established state and return a success response [1)]	All modifications take place immediately, once the connection has transitioned to the established state. Return error: the object cannot perform the requested service in its current mode/state (general error code value = $0C_{hex}$)	Error: the object cannot perform the requested service in its current mode/ state (general error code value = $0C_{hex}$)

Table 20 *(continued)*

I/O connection object state					
Event	**Non-existent**	**Configuring**	**Waiting for CID**	**Established**	**Timed-out**
Receive_data	Not applicable	Discard the message	Discard the message	If a complete, valid message [2] has been received, reset the inactivity/ watchdog timer [3] and deliver the I/O message to the application	Discard the message
Send_message	Not applicable	Return internal error – do not send the message	Return internal error – do not send the message	Examine the connection_size attribute of the connection and transmit the message, fragmented if necessary	Return internal error – do not send the message
Inactivity/watch dog timer expires	Not applicable	Not applicable	Not applicable	Examine the watchdog_time-out_action attribute of the connection and perform the indicated action	Not applicable

[1] If the configuration indicates that a message ID needs to be allocated and an available message ID does not exist in the specified message group, then an error response whose general error code indicates resource unavailable (02_{hex}) is returned. If a connection object attribute value passed the range check when it was initially configured but the attribute value conflicts with another piece of information in the node when the apply request is processed, then an error response is returned whose general error code is set to invalid attribute value (09_{hex}) and whose additional code is set to the attribute ID of the offending connection object attribute ID.

[2] The connection object verifies that the length of the received I/O message is less than or equal to the consumed_connection_size attribute prior to processing the message. If the length of the received message is less than or equal to the consumed_connection_size attribute, then the I/O connection object resets the inactivity/watchdog timer, exhibits the externally visible behaviour indicated by its attribute settings, and delivers the message to the application. If the length of the received message is greater than the consumed_connection_size attribute, then the I/O connection object immediately discards the message and discontinues any subsequent processing. This is the only message content validation performed by an I/O connection object. Any subsequent validation shall be performed by the application.

[3] If a fragmented message is being received, then the inactivity/watchdog timer is not reset until the entire message has been received.

Figure 25 provides a general overview of the behaviour associated with an explicit messaging connection.

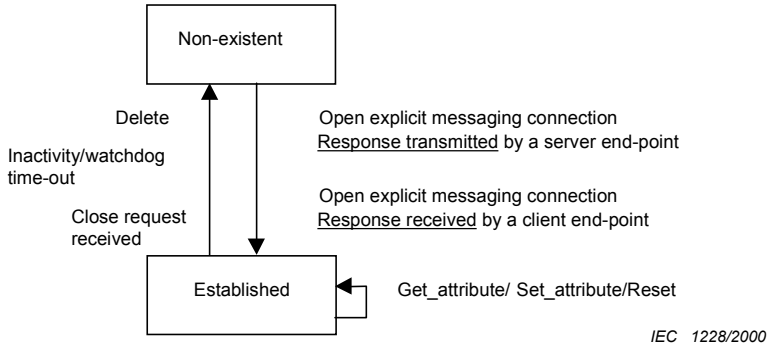


Figure 25 – Explicit messaging connection object state transition diagram

Table 21 provides a detailed state-event matrix for an explicit messaging connection.

Table 21 – Explicit messaging connection state-event matrix

Explicit messaging connection object state		
Event	**Non-existent**	**Established**
UCMM receives an open explicit messaging connection request/response and invokes the create service of the connection class	If possible, class creates connection object with the instance_type attribute set to explicit messaging [1)] Other attributes are automatically configured using the information in the open explicit messaging connection request/response. Transition to established If request received, transmit open explicit messaging connection response	Not applicable
UCMM receives a close request	Error: object does not exist (general error code 16_{hex})	Release all associated resources Transition to non-existent
Connection class receives a delete request	Error: object does not exist (general error code 16_{hex})	Release all associated resources Transition to non-existent
Set_attribute_single	Error: object does not exist (general error code 16_{hex})	Validate/service the request according to 5.3.2.8 Return response
Get_attribute_single	Error: object does not exist (general error code 16_{hex})	Validate/service the request according to 5.3.2.8 Return response
Reset	Error: object does not exist (general error code 16_{hex})	Cancel the current inactivity/watchdog timer. Using the value in the expected_packet_rate attribute, restart the inactivity/watchdog timer
Apply_attributes	Error: object does not exist (general error code 16_{hex})	Error: the object cannot perform the requested service in its current mode/state (general error code value = $0C_{hex}$)
Receive_data	Not applicable	If a valid message or message fragment has been received, then reset the inactivity/watchdog timer [2)]. Either process/store the fragment or handle the explicit message
Send_message	Not applicable	Examine the length of the message to transmit and transmit the message, fragmented if necessary
Inactivity/watchdog timer expires	Not applicable	Release all associated resources Transition to non-existent

[1)] If the configuration indicates that a message ID needs to be allocated and an available message ID does not exist in the specified message group, then an error response whose general error code indicates resource unavailable (02_{hex}) is returned.

[2)] The MAC ID field within the message header of all explicit messages and/or message fragments is examined. If the destination MAC ID is specified in the CID (CAN identifier field), then the source MAC ID of the other end-point shall be specified in the message header. If the source MAC ID is specified in the CID, then the receiving node's MAC ID shall be specified in the message header. If either of these checks fail, then the inactivity/watchdog timer is not reset and the message/message fragment is discarded.

5.3.2.8 Connection object attribute access rules

During the configuration of a connection instance using the set_attribute service, a node shall check the value of each separate attribute which is to be modified. If an error is detected, then an error response shall be returned.

If the produced_connection_id and/or consumed_connection_id attributes contain a non-default value upon reception of the apply request, then the relevant portion of the initial_ comm_characteristics attribute is ignored and the ID value is validated and used.

Table 22 and table 23 indicate when an attribute can be read or written via a get or set operation based on the connection's state and instance_type.

If a request to get/set a supported attribute is received but the current state and/or type of connection dictates that the requested access is invalid, then the returned error status indicates that the object cannot perform the requested service in its current mode/state (general error code value = $0C_{hex}$). Error codes are specified in annex B.

Table 22 – I/O connection object attribute access

I/O connection state					
Attribute	**Non-existent**	**Configuring**	**Waiting for CID**	**Established**	**Timed-out**
State	Not available	Get only	Get only	Get only	Get only
Instance_type	Not available	Get only	Get only	Get only	Get only
Transportclass_trigger	Not available	Get/set	Get only	Get only	Get only
Produced_connection_id	Not available	Get/set	Get/set	Get/set	Get/set
Consumed_connection_id	Not available	Get/set	Get/set	Get/set	Get/set
Initial_comm_characteristics	Not available	Get/set	Get only	Get only	Get only
Produced_connection_size	Not available	Get/set	Get only	Get only	Get only
Consumed_connection_size	Not available	Get/set	Get only	Get only	Get only
Expected_packet_rate [1)]	Not available	Get/set	Get only	Get/set	Get/set
Watchdog_timeout_action	Not available	Get/set	Get only	Get/set	Get/set
Produced_connection_path_length	Not available	Get only	Get only	Get only	Get only
Produced_connection_path	Not available	Get/set	Get only	Get only	Get only
Consumed_connection_path_length	Not available	Get only	Get only	Get only	Get only
Consumed_connection_path	Not available	Get/set	Get only	Get only	Get only
Production_inhibit_time	Not available	Get/set	Get only	Get/set	Get/set

1) When a connection object is in the established state, any modifications to the expected_packet_rate attribute have immediate effect on the inactivity/watchdog timer. The following steps are performed by a connection object in the established state when a request is received to modify the expected_packet_rate attribute:

– the current inactivity/watchdog timer is cancelled;

– a new inactivity/watchdog timer is activated based on the new value in the expected_packet_rate attribute.

Table 23 – Explicit messaging connection object attribute access

Explicit messaging connection state		
Attribute	**Non-existent**	**Established**
State	Not available	Get only
Instance_type	Not available	Get only
Transportclass_trigger	Not available	Get only
Produced_connection_id	Not available	Get only
Consumed_connection_id	Not available	Get only
Initial_comm_characteristics	Not available	Get only
Produced_connection_size	Not available	Get only
Consumed_connection_size	Not available	Get only
Expected_packet_rate [1)]	Not available	Get/set [1)]
Watchdog_timeout_action	Not available	Get only
Produced_connection_path_length	Not available	Get only
Produced_connection_path	Not available	Get only
Consumed_connection_path_length	Not available	Get only
Consumed_connection_path	Not available	Get only
Production_inhibit_time	Not available	Get only

[1)] When a connection object is in the established state, any modifications to the expected_packet_rate attribute have immediate effect on the inactivity/watchdog timer. The following steps are performed by a connection object in the established state when a request is received to modify the expected_packet_rate attribute:

– the current inactivity/watchdog timer is cancelled;

– a new inactivity/watchdog timer is activated based on the new value in the expected_packet_rate attribute.

5.3.2.9 Dynamic management of message IDs

Dynamically establishing both I/O and explicit messaging connections requires all end-points to implement internal message ID allocation procedures. These procedures shall also mark a previously allocated message ID as available when that message ID is no longer in use.

To reduce the likelihood of CID errors, the following rules shall be followed:

a) the CID allocation process shall ensure that no two nodes on DeviceNet have configurations that allow transmission of an identical bit pattern within the CAN identifier field;

b) the CID deallocation process shall ensure that all end-points of a connection have timed-out prior to reusing a message ID:

   – if the message ID is associated with a connection that activates an inactivity/watchdog timer, then a new inactivity/watchdog timer is activated. Upon expiration of this timer, the message ID is marked as available;

   – if the message ID is associated with a connection that does not activate an inactivity/watchdog timer, then the message ID can be immediately marked as available.

5.3.3 DeviceNet object class definition (class ID code: 3)

5.3.3.1 General

The DeviceNet object is used to provide the configuration and status of a physical attachment to DeviceNet. A product shall support one DeviceNet object per physical link attachment.

5.3.3.2 DeviceNet object class attributes

The class attributes for the DeviceNet object are defined in table 24.

Table 24 – Class attributes for the DeviceNet object

Attribute ID	Need in implementation	Access rule	Attribute name	Data type	Attribute description	Value
1	Required	Get	Revision	UINT	Revision of the object	2

5.3.3.3 DeviceNet object class common services

The DeviceNet object class shall support the DeviceNet common services shown in table 25.

Table 25 – DeviceNet object class common services

Need in Implementation	Service name	Service description
Required	Get_attribute_single	Reads a DeviceNet object class attribute
NOTE Service codes are defined in annex A.		

5.3.3.4 DeviceNet object instance attributes

Table 26 defines the instance attributes for the DeviceNet object.

Table 26 – Instance attributes for the DeviceNet object

Attribute ID	Need in implementation	Access rule	Name	Data type	Brief description of attribute	Values
1	Optional	Get/set	MAC ID	USINT	Node address	Range 0-63
2	Optional	Get/set	Bit rate	USINT	Bit rate	Range 0-2
3	Optional	Get/set	BOI	BOOL	Bus-off interrupt	
4	Optional	Get/set	Bus-off counter	USINT	Number of times CAN went to the bus-off state	Range 0-255
5	Optional [1)]	Get	Allocation information	STRUCT		
			Allocation choice byte	BYTE	See 5.3.3.5.2.1.2	
			Master's MAC ID	USINT	MAC ID of master (from allocate)	Range 0-63 and 255 Modified via allocate only
6	Optional	Get	MAC ID switch changed	BOOL	Node address switch(es) have changed since last power-up/reset	0 = no change 1 = change since last reset or power-up
7	Optional	Get	Bit rate switch changed	BOOL	Bit rate switch(es) have changed since last power-up/reset	0 = no change 1 = change since last reset or power-up

Table 26 *(continued)*

Attribute ID	Need in implementation	Access rule	Name	Data type	Brief description of attribute	Values
8	Optional	Get	MAC ID switch value	USINT	Actual value of node address switch(es)	Range 0-63
9	Optional	Get	Bit rate switch value	USINT	Actual value of bit rate switch(es)	Range 0-2
[1)] The allocation information attribute shall be supported if the predefined master/slave connection set is supported.						

Some attributes are described below.

1) **MAC ID**

This attribute contains the MAC ID of this device. A device that uses switches which are user accessible when the product is installed to set the MAC ID shall return an error response whose general error code is set to $0E_{hex}$ (attribute not settable) in response to a set_attribute_ single request specifying the MAC ID attribute. The MAC ID attribute is considered non-volatile in that, once configured, the attribute shall be remembered after a power cycle or device reset. The default value of the MAC ID shall be 63.

Modification of the MAC ID requires that a device deletes all connection objects and re-executes the link access state machine defined in 5.4.

2) **Bit rate**

The bit rate attribute indicates the selected bit rate. Values are shown in table 27.

Table 27 – Bit rate attribute values

Value	Meaning
0	125 kbit/s
1	250 kbit/s
2	500 kbit/s
3-255	Reserved

A device that uses switches which are user accessible when the product is installed to set the bit rate shall return an error response whose general error code is set to $0E_{hex}$ (attribute not settable) in response to a set_attribute_single request specifying the bit rate attribute. The bit rate attribute is considered non-volatile in that, once configured, the attribute shall be remembered after a power cycle or device reset. The default bit rate shall be 125 kbit/s.

Modification of the bit rate shall not take effect until the device is either physically reset or reset by sending the reset service to the identity object.

3) **Bus-off interrupt** (BOI) (as described in table 28)

The bus-off interrupt attribute consists of one bit that defines how a CAN device processes the bus-off interrupt.

Table 28 – BOI attribute values

Value	Meaning
FALSE	Hold the CAN chip in its bus-off (reset) state upon detection of a bus-off indication
TRUE	If possible, fully reset the CAN chip and continue communicating upon detection of a bus-off indication

When the bus-off interrupt attribute is FALSE (set to 0) and a CAN chip bus-off event is detected:

– the transceiver shall be held in its reset/bus-off state;

– the device shall enter the communication fault state (see 5.4).

When the bus-off interrupt attribute is TRUE (set to 1) and a CAN chip bus-off event is detected, it may be possible to return the MAC and transceiver implementation to its normal operating mode and continue communicating based on the link access state machine detailed in 5.4.

If the bus-off interrupt attribute is not supported, the device shall implement the behaviour indicated by attribute value FALSE in table 28.

4) **Bus-off counter**

The bus-off counter is initialised to 0 at power-up or device initialisation.

The bus-off counter stops counting when it reaches maximum count.

The DeviceNet object resets the bus-off counter to 0 whenever it receives a set_attribute_ single request specifying the bus-off counter attribute. The set_attribute_single data is not used and can be any value.

5) **Allocation information**

The allocation information attribute shall be supported if the predefined master/slave connection set is supported. It indicates whether or not the predefined master/slave connection set defined in 5.5 has been allocated. If it has been allocated, then this attribute indicates the device that has performed the allocation and the connection(s) that are currently allocated.

This attribute is modified when a success response associated with an allocate_master/ slave_connection_set service (defined in 5.5) is generated. This attribute is not modifiable by the set_attribute_single service. An error response whose general error code field is set to $0E_{hex}$ (attribute not settable) is returned if a set_attribute_single request specifies this attribute.

The allocation information attribute consists of the following:

– **allocation choice byte**

  The allocation choice byte indicates which of the predefined master/slave connections are active (in the configuring or established state). Its format is specified in 5.3.3.5.2.1.2.

  The allocation choice byte is initialised to 00 at device power-up or reset.

– **master's MAC ID**

  The master's MAC ID contains the MAC ID of the device that has allocated the predefined master/slave connection set via the allocate_master/slave_connection_set service. This contains the allocator's MAC ID field copied from the allocate_master/slave_ connection_set request.

The range of values is 0-63 and 255 decimal. A value in the range 0-63 indicates that the predefined master/slave connection set is currently allocated and denotes the MAC ID of the device that performed the allocation. The value 255 means the predefined master/ slave connection set has not been allocated.

The master's MAC ID attribute is initialised to 255 at device power-up/reset.

5.3.3.5 DeviceNet object instance services

The subclauses that follow describe the common services and object class-specific services supported by the DeviceNet object instance.

5.3.3.5.1 Common services

The DeviceNet object instance shall support the common services shown in table 29.

Table 29 – DeviceNet object instance common services

Need in implementation	Service name	Service description
Required	Get_attribute_single	Reads a DeviceNet object attribute value
Optional	Set_attribute_single	Modifies a DeviceNet object attribute value
NOTE Service codes are defined in annex A.		

5.3.3.5.2 Object class-specific services

The DeviceNet object instance shall support the object class-specific services shown in table 30.

Table 30 – DeviceNet object class-specific services

Service code	Need in implementation	Service name	Service description
$4B_{hex}$	Optional	Allocate_master/ slave_connection_set	Requests the use of the predefined master/slave connection set
$4C_{hex}$	Optional	Release_master/ slave_connection_set	Indicates that the specified connections within the predefined master/slave connection set shall be deleted

These services are used to allocate and deallocate the predefined master/slave connection set described in 5.5.

A device that behaves as the client across the predefined master/slave connection set is referred to as a master. A device that behaves as the server across the predefined master/slave connection set is referred to as a slave.

Before a device can function as a master, it shall first allocate the predefined master/slave connection set within the slave. Only one master shall have the predefined master/slave connection set allocated at any given time. When a master no longer requires its slave, it shall release all connections, causing the slave to deallocate the predefined master/slave connection set.

5.3.3.5.2.1 Allocate_master/slave_connection_set (service code: $4B_{hex}$)

5.3.3.5.2.1.1 General

This service allocates the predefined master/slave connection set. General error codes are defined in annex B. DeviceNet object-specific additional error code values are defined in 5.3.3.6. This service shall be transmitted using either the unconnected explicit request message of the master/slave connection set (see 5.5.2) or an explicit messaging connection.

The allocate_master/slave_connection_set service performs the following:

– connection object create;

– connection object configure.

See 9.3.4 and 9.3.5 for test specifications regarding the allocation of the master/slave connection set for both explicit and I/O messaging connections.

5.3.3.5.2.1.2 Request service data field parameters

The information in table 31 is specified within the service data field of an allocate_master/ slave_connection_set request.

Table 31 – Allocate_master/slave_connection_set request service data field parameters

Name	Data type	Description of parameter
Allocation choice	BYTE	Indicates which connections from the predefined master/slave connection set are to be allocated/configured for use by the master
Allocator's MAC ID	USINT	Contains the MAC ID associated with the node requesting the allocation

The allocation choice parameter is specified within a single byte (see figure 26). Each bit denotes an explicit message and/or I/O connection(s) from the predefined master/slave connection set that are to be allocated, or, in the case of an acknowledgement suppression, a command. If the bit is set to 1, then a request is being made to allocate the corresponding connection. If a bit is set to 0, then the requester does not want to allocate the corresponding connection.

7	6	5	4	3	2	1	0
Reserved	Acknowledgement suppression	Cyclic	Change of state	Reserved	Bit strobed	Polled	Explicit message

IEC 1229/2000

Figure 26 – Allocation choice byte contents

Bits 3 and 7 shall be set to 0 and the slave shall verify this requirement when the allocate_ master/slave_connection_set request is received.

Figure 27 shows the format of this explicit message.

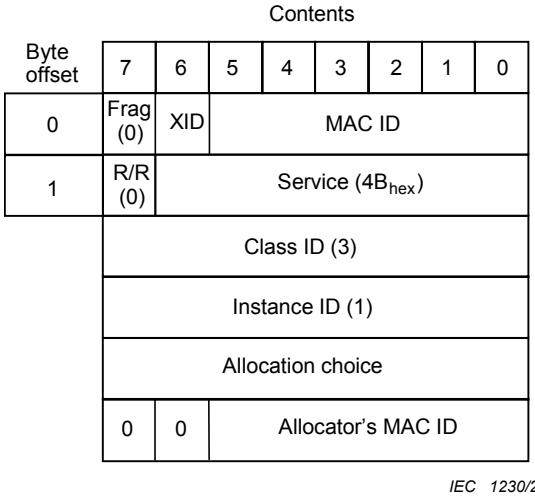


Figure 27 – Allocate_master/slave_connection_set request message

Allocate_master/slave_connection_set request message contents:

– **frag (0)/transaction ID/MAC ID:** as defined in 5.2.1.2;

– **R/R bit (0):** indicates this is a request message;

– **service code (4B$_{hex}$):** identifies this message as an allocate_master/slave_ connection_ set service;

– **class ID:** defines the object class to which this request is directed. When this message is transmitted across the unconnected explicit request message port of the master/slave connection set (see 5.5.2), the class ID value is specified within an 8-bit integer field. The class ID shall be set to 3;

– **instance ID:** defines the particular instance within the object class to which this request is directed. When this message is transmitted across the unconnected explicit request message port of the master/slave connection set (see 5.5.2), the instance ID value is specified within an 8-bit integer field. The instance ID shall be set to 1;

– **allocation choice:** specified by the byte following the instance ID field;

– **allocator's MAC ID:** specified within the byte following the allocation choice field.

5.3.3.5.2.1.3 Success response service data field parameters

The information contained within the service data field of a successful allocate_master/slave_ connection_set response is described in table 32.

Table 32 – Allocate_master/slave_connection_set response parameters

Name	Data type	Description of parameter
Message body format	Defined below	This parameter is semantically equivalent to the actual message body format parameter returned with an open explicit message connection response message (as described in 5.2.1.6). This argument is significant when the allocate_master/slave_connection_set request was received across the unconnected explicit request message port of the master/slave connection set (see 5.5.2). It indicates the message body format associated with subsequent messages transmitted across the explicit messaging connection within the predefined master/slave connection set. If the allocate_master/slave_connection_set request was received across an explicit messaging connection within a UCMM capable device, then this parameter is set to the actual message body format associated with that explicit messaging connection.

Figure 28 shows the format of a success response to the allocate_master/slave_ connection_ set request.

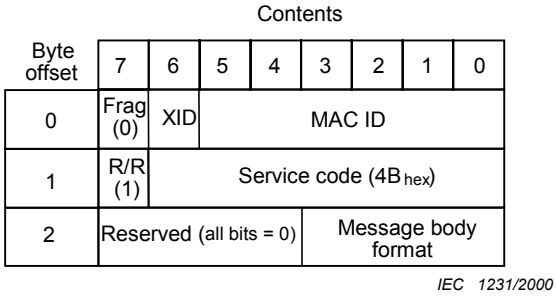


Figure 28 – Success response to allocate_master/slave_connection_set request

Allocate_master/slave_connection_set request success response contents:

– **frag (0)/transaction ID/MAC ID:** as defined in 5.2.1.2;

– **R/R bit (1):** indicates this is a response message;

– **service code ($4B_{hex}$):** identifies this message as an allocate_master/slave_connection_ set service;

– **reserved bits:** these bits are not used by the receiver of the response and shall be set to 0 by the transmitter of the response message;

– **message body format:** as described in table 32.

5.3.3.5.2.2 Allocate_master/slave_connection_set server behaviour

1) If an error is encountered, then none of the requested connections shall be allocated. If this request cannot be fully serviced, then none of the requested allocations shall take place.
2) If the receiving device does not support the predefined master/slave connection set, then an error response is returned. The general error code within the error response shall be set to 08 to indicate service not supported.
3) The receiving device (slave) validates the allocator's MAC ID parameter within the request as follows:
   – if the predefined master/slave connection set is allocated and this request is not from the current master, then the slave returns an error. The general error code within the error response shall be set to $0C_{hex}$, with the additional error code set to an object-specific value of 01;
   – if the predefined master/slave connection set is not allocated, then the slave validates the allocation choice parameter as specified in item 4);
   – if the predefined master/slave connection set is allocated and this request is from the current master, then the slave shall validate the allocation choice parameter as specified in item 4).
4) The slave shall validate the allocation choice parameter within the request. If the slave does not support one of the connections specified in the allocation choice argument, then an error response shall be returned. The general error code within the error response shall be set to 02, with the additional error code set to an object-specific value of 02.

   If any of the connections being requested are supported by this slave and have already been allocated to the master denoted by the allocator's MAC ID argument, the slave shall return an error response with the general error code set to $0B_{hex}$, with the additional error code set to an object-specific value of 02. If the requested I/O connection is in the timed-out state, the slave shall reallocate the I/O connection, setting it to the configuring state.

If the allocation choice byte has no bits set, the slave shall return an error response with the general error code set to 09, with the additional error code set to an object-specific value of 02.

If a resource that is required for use with the requested connections is not available, then an error response shall be returned with the general error code set to 02, and the additional error code set to an object-specific value of 04.

The change of state and cyclic allocation choices are mutually exclusive. If an allocation request would result in both the cyclic and change of state bits being set, an error response shall be returned. The general error code within the error response shall be set to 09 (invalid attribute value) with an additional error code of 02.

If a master has allocated the change of state/cyclic connection set and a subsequent allocation request is received with the polled allocation bit set, an error shall be returned. The general error code within the error response shall be set to 02 to indicate resource unavailable. If the allocation choice byte has the acknowledgement suppression bit set and neither the change of state bit nor the cyclic bit are set, an error response shall be returned. The general error code within the error response shall be set to 09 with an additional error code of 02.

5) The slave notes the fact that the predefined master/slave connection set has been allocated to the MAC ID within the allocator's MAC ID field by updating the DeviceNet object's allocation information attribute. If necessary, the produced_connection_id and/or consumed_connection_id attributes of the connection object(s) may now be initialised.

   The allocation choice byte of the allocation information attribute indicates which connection objects from the predefined master/slave connection set are active (in the configuring, or established state). This byte is updated whenever a master/slave connection object changes state.

6) Any allocated I/O connection(s) transition to the configuring state. With respect to the predefined master/slave connection objects, an implied apply_attributes service accompanies a set_attribute_single of the expected_packet_rate attribute while the connection is in the configuring state. A set_attribute_single of the expected_packet_rate attribute triggers the execution of the steps performed with an apply_attributes service and causes the predefined master/slave I/O connection object to transition to the established state. If an error is encountered when performing the apply_attributes portion, then the expected_packet_rate attribute shall be reset to its previous value, and an error shall be returned whose general error code is set to 09 and whose additional error code is set to the offending connection object's attribute ID.

7) If allocated, the explicit messaging connection transitions to the established state. The inactivity/watchdog timer is started using the initial value specified in 5.3.2.5.3.

   UCMM capable devices which support the predefined master/slave connection set shall support the allocation and use of the predefined master/slave connection set explicit messaging connection.

8) Either the master/slave connection set's explicit messaging connection or a dynamically established explicit messaging connection acts as the allocated I/O connection(s) parent until the I/O connection(s) are in the established state. The term parent is used to indicate that, if the explicit messaging connection is deleted and none of the allocated I/O connections exist in the established state, then the predefined master/slave connection set is automatically released by the slave. The logic describing which explicit messaging connection is to act as the parent is defined in figure 29.

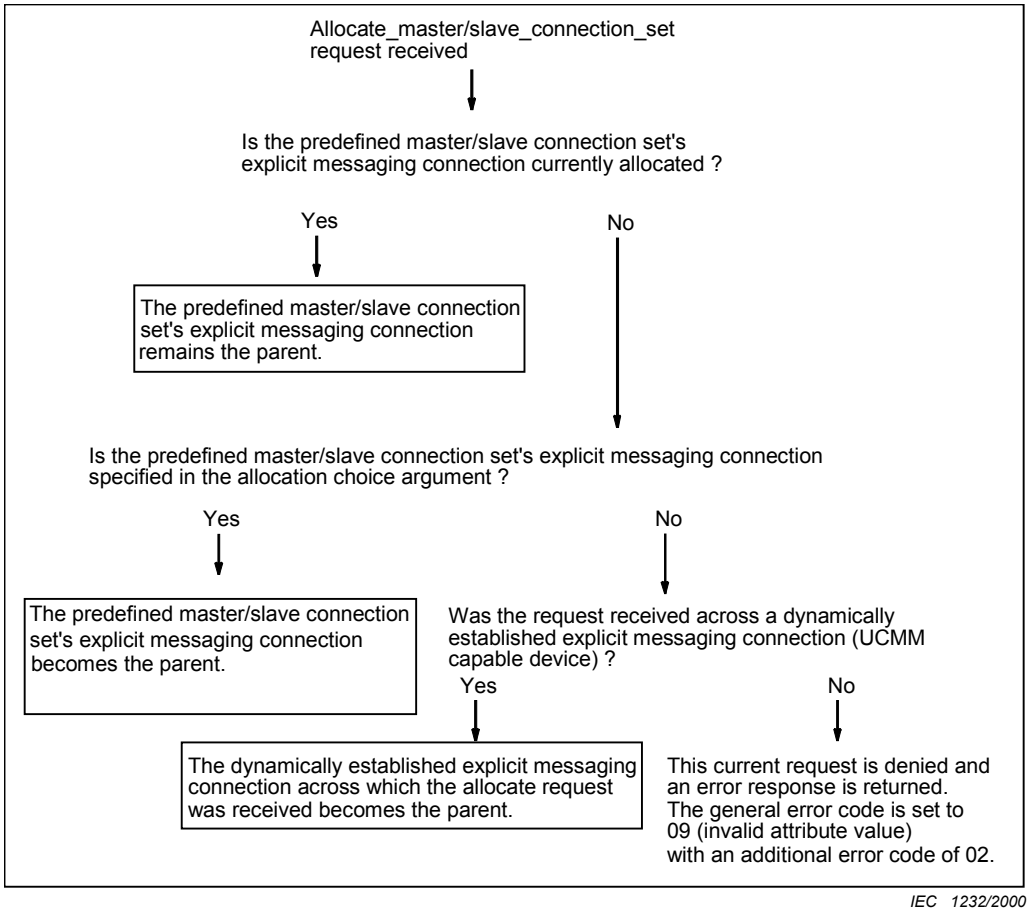


Figure 29 – Parent explicit messaging connection logic

The slave automatically releases the predefined master/slave connection set and all connections return to the non-existent state if all of the following conditions are true:

– none of the connection objects associated with the predefined master/slave connection set exist in the established state;
– the parent explicit messaging connection object is not in the established state.

5.3.3.5.2.3 Release_master/slave_connection_set (service code: $4C_{hex}$)

5.3.3.5.2.3.1 General

This service is used to deallocate the predefined master/slave connection set within a slave. General error codes are defined in annex B. DeviceNet object-specific additional error code values are defined in 5.3.3.6. This service can be transmitted across the unconnected explicit request message port of the master/slave connection set (see 5.5.2) as well as across an explicit messaging connection.

5.3.3.5.2.3.2 Request service data field parameters

The information in table 33 is specified within the service data field of a release_master/ slave_connection_set request.

Table 33 – Release_master/slave_connection_set request service data field parameters

Name	Data type	Description of parameter
Release choice	BYTE	Indicates which predefined master/slave connections are to be released

The release choice parameter is specified within a single byte (see figure 30). Each bit denotes an explicit message and/or I/O connection(s) to be released. If the bit is set to 1, then a request is being made to release the corresponding connection. If a bit is set to 0, then the requester does not want to release the corresponding connection.

7	6	5	4	3	2	1	0
Reserved	Acknow-ledgement suppression	Cyclic	Change of state	Reserved	Bit strobed	Polled	Explicit message

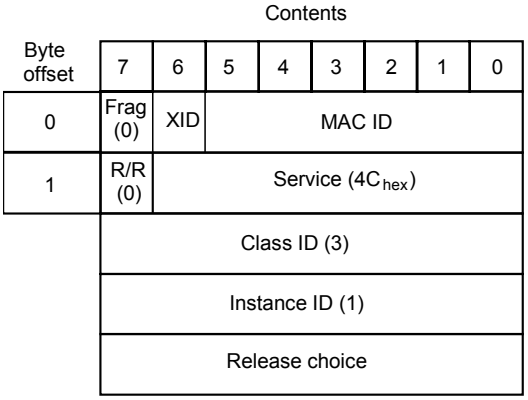
IEC 1233/2000

Figure 30 – Release choice byte contents

Bits 3 and 7 shall be set to 0 and the slave shall verify this requirement when the release_ master/slave_connection_set request is received.

A value of 00 is invalid.

Figure 31 shows the format of this explicit message.



IEC 1234/2000

Figure 31 – Release_master/slave_connection set request message

Release_master/slave_connection set request message contents:

– **frag (0)/transaction ID/MAC ID:** see 5.2.1.2;

– **R/R bit (0):** indicates this is a request message;

– **service code ($4C_{hex}$):** identifies this message as a release_master/slave_connection_set service;

– **class ID:** defines the object class to which this request is directed. When this message is transmitted across the unconnected explicit request message port of the master/slave connection set (see 5.5.2), the class ID value is specified within an 8-bit integer field. The class ID shall be set to 3;

– **instance ID:** defines the particular instance within the object class to which this request is directed. When this message is transmitted across the unconnected explicit request message port of the master/slave connection set (see 5.5.2), the instance ID value is specified within an 8-bit integer field. The instance ID shall be set to 1;

– **release choice:** specified within the byte following the instance ID field.

5.3.3.5.2.3.3 Success response message

Figure 32 shows the format of a success response to the release_master/slave_ connection_ set request.

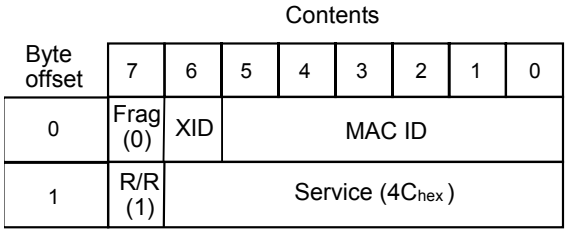


Figure 32 – Success response to release_master/slave_connection_set request

Release_master/slave_connection_set request success response contents:

– **frag (0)/transaction ID/MAC ID:** see 5.2.1.2;

– **R/R bit (1):** indicates this is a response message;

– **service code ($4C_{hex}$):** identifies this as a release_master/slave_connection_set service.

5.3.3.5.2.4 Release_master/slave_connection_set server behaviour

If an error is encountered, then none of the specified connections are released. If this request cannot be fully serviced, then none of the requested releases take place.

If the receiving device does not support the predefined master/slave connection set, then an error response shall be returned. The general error code within the error response shall be set to 08.

The receiving device (slave) shall validate the release choice parameter within the request. If the slave does not support one of the connections specified in the release choice argument, then an error response shall be returned. The general error code within the error response shall be set to 02, with the additional error code set to an object-specific value of 02.

If the release choice byte has no bits set (all bits are 0), the slave shall return an error response with the general error code set to 09 (invalid attribute value), with the additional error code set to an object-specific value of 02.

If one of the specified connections is in the non-existent state, then an error response shall be returned. The general error code within the error response shall be set to $0B_{hex}$.

The slave shall verify that it is in a state that allows it to discontinue use of the specified connection(s). If this is not the case, then an error response shall be returned. The general error code within the error response shall be set to $0C_{hex}$.

If the request is valid, then the slave shall release all resources associated with the specified connection(s). If this results in all predefined master/slave connections being released, the slave shall note the fact that the predefined master/slave connection set is no longer allocated by updating the allocation information attribute.

The slave shall not check to see that the release request came from its master.

If this request has resulted in none of the predefined master/slave connections existing in the established state, then the slave shall release the predefined master/slave connection set and all connections shall return to the non-existent state.

5.3.3.6 Error codes specific to the DeviceNet object

Table 34 lists additional error codes specific to the DeviceNet object.

Table 34 – DeviceNet object-specific additional error codes

Value	Meaning
01	Predefined master/slave connection set allocation conflict. This is returned when an allocate_master/slave_connection_set request is received and the slave has already allocated the predefined master/slave connection set to another master
02	Invalid allocation/release choice parameter. This is returned when an allocate/release_master/ slave_connection_set request is received and: 1) the slave does not support the choice specified in the choice parameter; 2) the slave was asked to allocate/release connection(s) already allocated/released; 3) the allocation choice/release byte contained all zeros, an invalid combination of bits, or did not contain the explicit message allocation choice when required
03	A server that does not support UCMM received a message that was not an allocate or release message on the unconnected explicit request message port of the master/slave connection set (see 5.5.2)
04	Resource required for use with the predefined master/slave connection set is unavailable

5.4 Link access state machine

5.4.1 General

This subclause defines the link access state machine that every DeviceNet node shall implement. The link access state machine is described by the following:

– tasks that shall be performed prior to communicating through the CDI;
– link events that affect a node's ability to communicate through the CDI.

5.4.2 State transition diagram and state-event matrix

Figure 33 provides a general overview of the link access state machine.

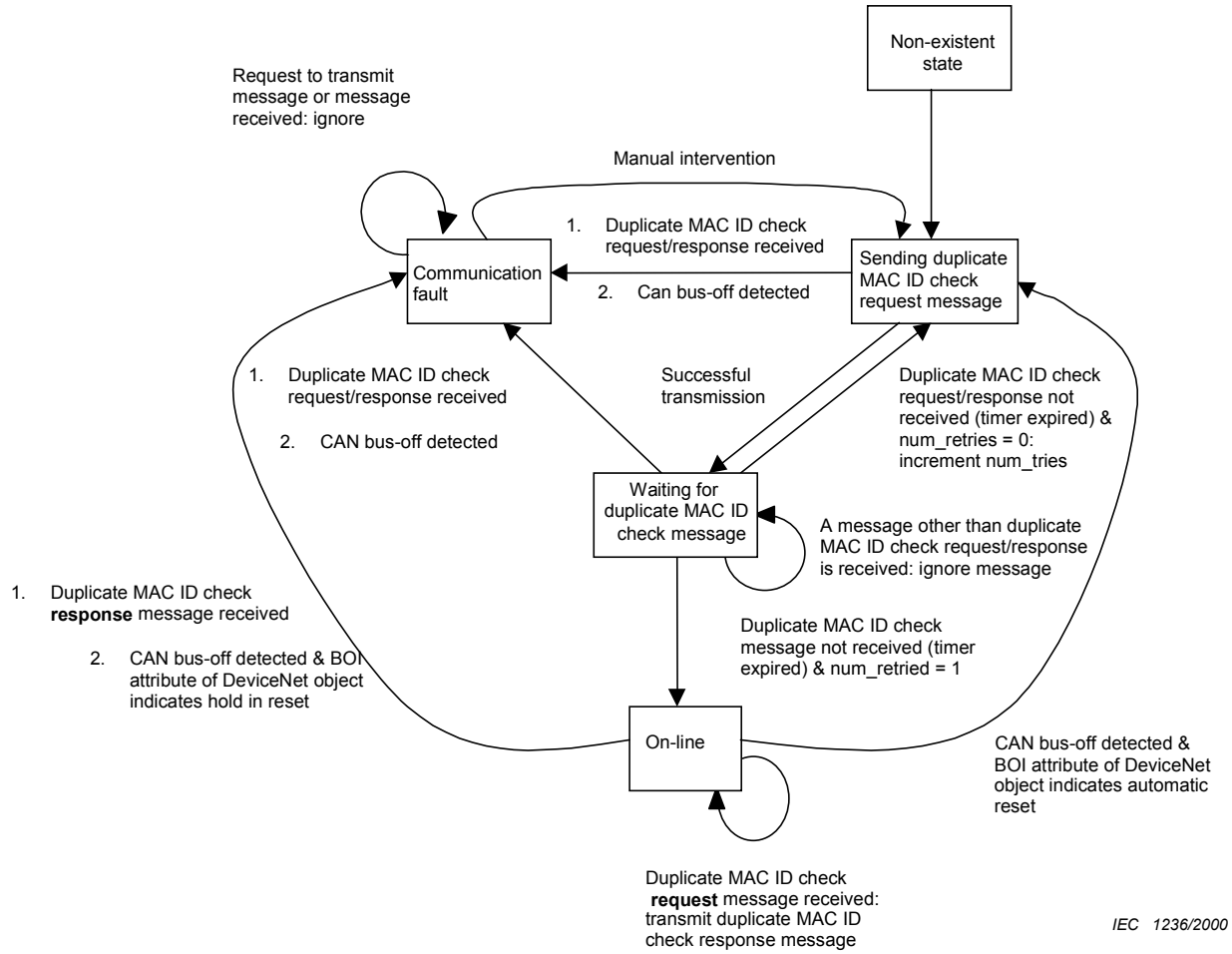


Figure 33 – Link access state transition diagram

Table 35 provides a detailed state-event matrix for the link access state machine.

Table 35 – Link access state-event matrix

State				
Event	**Sending duplicate MAC ID check request**	**Waiting for duplicate MAC ID check message**	**On-line**	**Communication fault**
Successful transmission of the duplicate MAC ID check request message	Activate 1 s timer [1)] Transition to waiting for duplicate MAC ID check message	Not applicable	Not applicable	Not applicable
Bus-off detected	Transceiver held in reset Transition to the communication fault state	Transceiver held in reset Transition to the communication fault state	Access the DeviceNet object's BOI attribute If the BOI attribute indicates that the transceiver shall be held in reset, then transition to communication fault If the BOI attribute indicates that the MAC and transceiver shall be automatically reset, then: 1) reset; 2) request the transmission of the duplicate MAC ID check request message; and 3) transition to the sending duplicate MAC ID check request state	Not applicable
Duplicate MAC ID check request message received	Duplicate MAC ID detected Transition to the communication fault state	Duplicate MAC ID detected Transition to the communication fault state	Transmit the duplicate MAC ID check response message	Discard message
Duplicate MAC ID check response message received	Duplicate MAC ID detected Transition to the communication fault state	Duplicate MAC ID detected Transition to the communication fault state	Duplicate MAC ID detected Transition to the communication fault state	Discard message
1 s duplicate MAC ID check message timer expires [1)]	Not applicable	If this is the first time-out, then request the transmission of the duplicate MAC ID check request message again and transition to sending duplicate MAC ID check request If this is the second consecutive time-out, then transition to on-line	Not applicable	Not applicable
Internal message transmission request	Return internal error	Return internal error	Transmit message	Return internal error
A message other than duplicate MAC ID check request/ response is received	Discard message	Discard message	Process the received message as appropriate	Discard message

[1)] Valid timer range is 0,9 s to 1,5 s.

The CAN fault confinement state machine considers the possibility that, during the system start-up/wake-up, only one node may be present on the link. If this node transmits a message, it will experience an acknowledgement error and will automatically repeat the message. In this situation, the node will transition to error passive but not bus-off. For this reason, the only event that signifies an unsuccessful transmission of a duplicate MAC ID check message (request or response) is the bus-off event. If an error passive or error warning indication is received during the transmission of a duplicate MAC ID check message, then it shall be ignored, as it has no effect on the duplicate MAC ID detection state machine.

5.4.3 Duplicate MAC ID detection

The main step involved in the link access state machine is the execution of a duplicate MAC ID detection algorithm. Each node on DeviceNet is assigned a unique MAC ID, and to protect against errors, all DeviceNet nodes shall participate in the duplicate MAC ID detection algorithm.

NOTE The protocol associated with the duplicate MAC ID detection algorithm is described in 5.2.4.

As stated in 5.2.4, a special message within message group 2 is defined for performing duplicate MAC ID detection.

A DeviceNet node shall receive and process any duplicate MAC ID check message that contains its MAC ID in the message group 2 identifier field.

After transmitting a duplicate MAC ID check request message, a module shall wait 1 s before timing out and taking the appropriate action defined by the link access state machine.

The duplicate MAC ID check request message shall be transmitted twice without receiving a subsequent duplicate MAC ID check request or response message before transitioning to on-line.

See 9.2.3 and 9.3.2 for test specifications regarding the power ON behaviour and handling of the duplicate MAC ID mechanisms.

5.5 Predefined master/slave connection set

5.5.1 General

The preceding subclauses present the general rules for establishing connections between devices. The general rules call for the utilisation of an explicit messaging connection to create and configure connection objects within each connection end-point. This subclause uses the general rules as a basis for the definition of a set of connections which facilitates communications typically seen in a master/slave relationship. These connections are referred to collectively as the predefined master/slave connection set.

– **Group 2 server:** An unconnected message manager (UCMM) capable device that has been configured to act as the server for the predefined master/slave identifier connections.
– **Group 2 client:** A UCMM capable device that has gained ownership of the predefined master/slave connection set within a server such that it may act as the client on those connections.
– **UCMM capable device:** A device that supports the UCMM.
– **UCMM incapable device:** A device that does not support the UCMM.

– **Group 2 only server:** A slave device that is UCMM incapable and uses the predefined master/slave connection set to establish communications. A group 2 only device can transmit and receive only those identifiers defined by the predefined master/slave connection set;
– **Group 2 only client:** A device that is acting as a group 2 client to a group 2 only server. The group 2 only client provides the UCMM functionality for group 2 only servers that are allocated to it.

5.5.2 Predefined master/slave connection set messages

The CAN identifier fields associated with the predefined master/slave connection set are shown in table 36, together with the identifiers that shall be used with all connection-based messaging used in the predefined master/slave connection set.

Table 36 – Predefined master/slave connection set identifier fields

Identifier bits											Usage	Range
10	9	8	7	6	5	4	3	2	1	0		
0	Group 1 message ID				Source MAC ID						Group 1 messages	000-3FF
0	1	1	0	1	Source MAC ID						Slave's I/O change of state or cyclic message	
0	1	1	1	0	Source MAC ID						Slave's I/O bit-strobe response message	
0	1	1	1	1	Source MAC ID						Slave's I/O poll response or change of state/cyclic acknowledgement message	
1	0	MAC ID						Group 2 message ID			Group 2 messages	400-5FF
1	0	Source MAC ID						0	0	0	Master's I/O bit-strobe command message	
1	0	Source MAC ID						0	0	1	Reserved	
1	0	Destination MAC ID						0	1	0	Master's change of state or cyclic acknowledgement message	
1	0	Source MAC ID						0	1	1	Slave's explicit response message	
1	0	Destination MAC ID						1	0	0	Master's explicit request message	
1	0	Destination MAC ID						1	0	1	Master's I/O poll command/change of state/cyclic message	
1	0	Destination MAC ID						1	1	0	Group 2 only unconnected explicit request message	
1	0	Destination MAC ID						1	1	1	Duplicate MAC ID check message	

The following types of messages are included in table 36:

– **I/O bit-strobe command/response message:** the bit-strobe command is an I/O message that is transmitted by the master. Multiple slaves may receive and react to the same bit-strobe command. The bit-strobe response is an I/O message that a slave transmits back to the master when the bit-strobe command is received;
– **I/O poll command/response message:** the poll command is an I/O message that is transmitted by the master. A poll command is directed to a specific slave. The poll response is an I/O message that a slave transmits back to the master when the poll command is received;

– **I/O change of state/cyclic message:** the change of state/cyclic message is transmitted by either the master or the slave. A change of state/cyclic message is directed to a specific node. An acknowledgement message shall be returned in response to this message unless the configuration includes suppression of acknowledgement messages;
– **explicit response/request message:** see 5.2.1.6;
– **group 2 only unconnected explicit request message:** the group 2 only unconnected explicit request port is used to allocate/release the predefined master/slave connection set;
– **duplicate MAC ID check message:** see 5.2.4.

5.5.3 Slave connection object characteristics

5.5.3.1 General

This subclause presents the externally visible characteristics of the connection objects associated with the predefined master/slave connection set within slave devices. The predefined master/slave connection objects described for slave devices are:

– **the bit-strobe connection:** responsible for receiving the master's bit-strobe command and returning the associated bit-strobe response;
– **the poll connection:** responsible for receiving the master's poll command and returning the associated poll response;
– **the explicit messaging connection:** responsible for the reception of explicit requests and returning associated responses;
– **the change of state/cyclic connection:** responsible for sending the change of state/cyclic message and receiving the acknowledgement response if not suppressed.

This subclause gives additional information for connection objects within the predefined master/slave connection set. Except where noted, all information specified in 5.3 applies to the connection objects described in this subclause.

5.5.3.2 Connection instance IDs

Every existing connection object has an assigned connection instance ID which identifies the connection object within the connection class. The connection instance IDs that shall be used by a slave device to identify predefined master/slave connection objects are shown in table 37.

Table 37 – Connection instance IDs for predefined master/slave connections

Connection instance ID	Description
1	Designates the explicit messaging connection into the server
2	Designates the poll I/O connection
3	Designates the bit-strobe I/O connection
4	Designates the slave's change of state or cyclic I/O connection

5.5.3.3 Predefined master/slave connection instance behaviour

Figure 34 illustrates the predefined master/slave I/O connection object state transition diagram.

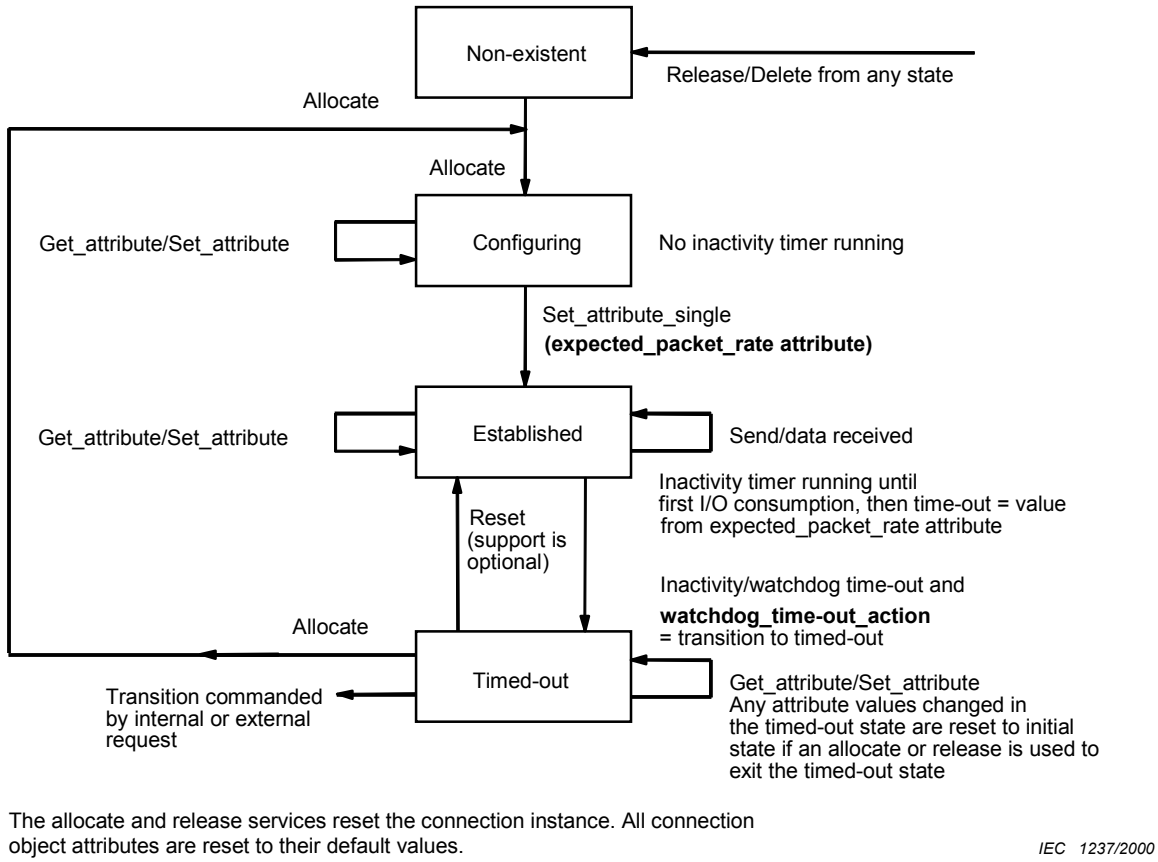


Figure 34 – Predefined master/slave I/O connection state transition diagram

For attribute modification, predefined master/slave I/O connections shall support at least the modification of the expected_packet_rate attribute.

The state-event matrix presented below provides a formal definition of the behaviour of I/O connections within the predefined master/slave connection set. This state-event matrix inherits from and/or overrides the actions presented in the I/O connection object state-event matrix in 5.3.

Table 38 – Predefined master/slave I/O connection state-event matrix

I/O connection object state				
Event	**Non-existent**	**Configuring**	**Established**	**Timed-out**
DeviceNet object receives an allocate master/slave connection set request that passes all error checks specified in 5.3.3.5.2.2 This request specifies one of the predefined master/slave I/O connections	Create a connection object for each requested I/O connection and set attributes to default values specified in 5.3.3.5.2.1 Transition to configuring	This is an error See 5.3.3.5.2.2	This is an error See 5.3.3.5.2.2	Set attributes to default values specified in 5.3.3.5.2.1 Transition to configuring
Connection class receives a delete request or the UCMM receives a close request and the request specifies a predefined master/slave I/O connection object	As described in table 20	Release all associated resources Transition to non-existent [1)]	Release all associated resources Transition to non-existent [1)]	Release all associated resources Transition to non-existent [1)]

Table 38 (continued)

I/O connection object state				
Event	**Non-existent**	**Configuring**	**Established**	**Timed-out**
DeviceNet object receives a release master/slave connection set request that passes all error checks specified in 5.3.3.5.2.2 This request specifies one of the predefined master/slave I/O connections	This is an error See 5.3.3.5.2.2	Release all associated resources Transition to non-existent [1)]	Release all associated resources Transition to non-existent [1)]	Release all associated resource Transition to non-existent [1)]
Set_attribute_single	As described in table 20	Validate/service the request according to the access rules presented in 5.5.3.4 If this is a valid request to set the expected_ packet_ rate attribute, then perform the steps specified in table 20 under the apply_ attributes event in the configuring state and transition to established. Return appropriate response	Validate/service the request according to the access rules presented in 5.5.3.4 Return appropriate response	Validate/service the request according to the access rules presented in 5.5.3.4 Return appropriate response
Get_attribute_single	As described in table 20	Validate/service the request according to the access rules presented in 5.5.3.4 Return appropriate response	Validate/service the request according to the access rules presented in 5.5.3.4 Return appropriate response	Validate/service the request according to the access rules presented in 5.5.3.4 Return appropriate response
Reset	As described in table 20	As described in table 20	As described in table 20	As described in table 20
Apply_attributes [2)]	As described in table 20	As described in table 20	As described in table 20	As described in table 20
Receive_data	As described in table 20	As described in table 20	As described in table 20	As described in table 20
Send_message	As described in table 20	As described in table 20	As described in table 20	As described in table 20
Inactivity/watchdog timer expires	As described in table 20	As described in table 20	As described in table 20 [1)]	As described in table 20

[1)] Whenever a connection object within the predefined master/slave connection set transitions out of the established state, the entire predefined master/slave connection set may need to be automatically released. When the predefined master/slave connection set is released, all associated connection objects return to the non-existent state. See 5.3.3.5.2.3 for more details concerning the automatic release of the predefined master/slave connection set.

[2)] Since an implied apply_attributes accompanies a set_attribute_single of the expected_packet_rate attribute of a predefined master/slave I/O connection object in the configuring state, the only time an apply_attributes explicit messaging request will succeed is when expected_packet_rate has yet to be successfully modified via the set_attribute_single request and, thus, still contains the default value of 0.

The state transition diagram (see figure 35) shows the behaviour of the predefined master/ slave explicit messaging connection.

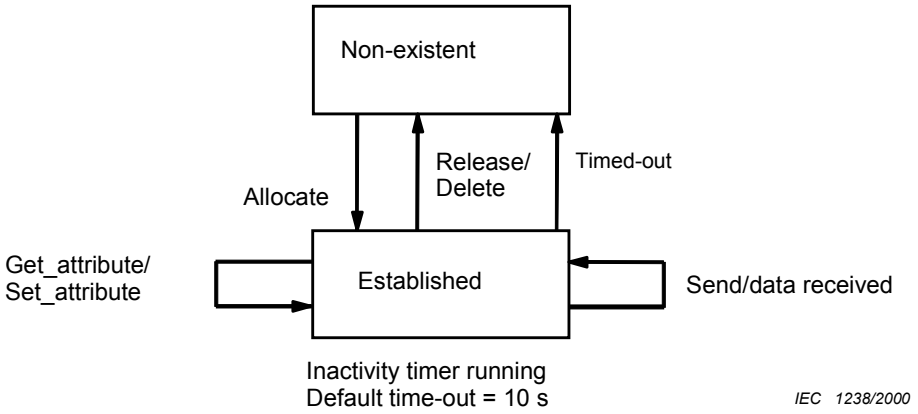


Figure 35 – Predefined master/slave explicit messaging state transition diagram

Table 39 provides a detailed state-event matrix for the predefined master/slave explicit messaging connection object. This state-event matrix inherits from and/or overrides the actions presented in the I/O connection object state-event matrix in 5.3.

Table 39 – Predefined master/slave I/O connection state-event matrix

Explicit messaging connection object state		
Event	**Non-existent**	**Established**
DeviceNet object receives an allocate master/slave connection set request that passes all error checks specified in 5.3.3.5.2.2 This request specifies the predefined master/slave explicit messaging connection	Create the predefined master/slave explicit messaging connection object for each requested I/O connection and set attributes to default values (see 5.3.3.5.2.1) Transition to established	This is an error See 5.3.3.5.2.2
UCMM receives a close request or the connection class receives a delete request, and the request specifies the predefined master/slave explicit messaging connection object	As described in table 21	As described in table 21
DeviceNet object receives a release master/slave connection set request that passes all error checks specified in 5.3.3.5.2.2 This request specifies the predefined master/slave explicit messaging connection	This is an error See 5.3.3.5.2.2	Release all associated resources Transition to non-existent [1)]
Set_attribute_single	As described in table 21	As described in table 21
Get_attribute_single	As described in table 21	As described in table 21
Reset	As described in table 21	As described in table 21
Apply_attributes	As described in table 21	As described in table 21
Receive_data	As described in table 21	As described in table 21
Send_message	As described in table 21	As described in table 21
Inactivity/watchdog timer expires	As described in table 21	As described in table 21

[1)] Whenever a connection object within the predefined master/slave connection set transitions out of the established state, the entire predefined master/slave connection set may need to be automatically released. When the predefined master/slave connection set is released, all associated connection objects return to the non-existent state. See 5.3.3.5.2.3 for more details concerning the automatic release of the predefined master/slave connection set.

5.5.3.4 Connection instance attribute access rules

Subclause 5.3.2.8 gives a general description of the access rules associated with connection objects. Table 40 shows access rules specific to the predefined master/slave I/O connection objects and inherits from and/or overrides the rules presented in 5.3.2.8.

Table 40 – Predefined master/slave I/O connection object attribute access

I/O connection state				
Attribute	**Non-existent**	**Configuring**	**Established**	**Timed-out**
State	As described in table 22	As described in table 22	As described in table 22	As described in table 22
Instance_type	As described in table 22	As described in table 22	As described in table 22	As described in table 22
Transportclass_trigger	As described in table 22	Get/set [1)]	As described in table 22	As described in table 22
Produced_connection_id	As described in table 22	Get only	Get only	Get only
Consumed_connection_id	As described in table 22	Get only	Get only	Get only
Initial_comm_characteristics	As described in table 22	Get only	Get only	Get only
Produced_connection_size	As described in table 22	Get/set[2)]	As described in table 22	As described in table 22
Consumed_connection_size	As described in table 22	Get/set	As described in table 22	As described in table 22
Expected_packet_rate	As described in table 22	As described in table 22	As described in table 22	As described in table 22
Watchdog_timeout_action	As described in table 22	As described in table 22	As described in table 22	As described in table 22
Produced_connection_path_length	As described in table 22	As described in table 22	As described in table 22	As described in table 22
Produced_connection_path	As described in table 22	As described in table 22	As described in table 22	As described in table 22
Consumed_connection_path_length	As described in table 22	As described in table 22	As described in table 22	As described in table 22
Consumed_connection_path	As described in table 22	As described in table 22	As described in table 22	As described in table 22

[1)] The transportclass_trigger attribute of a predefined master/slave I/O connection object within a slave device shall only be modifiable to one the following values: 82_{hex} – server/transport class 2, 83_{hex} – server/transport class 3.

[2)] The produced_connection_size attribute of the bit-strobe I/O connection shall not be settable to a value greater than 8.

5.5.4 Master connection object characteristics

This part does not present characteristics with respect to connection objects within a master. The master shall exhibit the external behaviour necessary to interface with its slaves.

5.5.5 Bit-strobe command/response messages

5.5.5.1 General

Bit-strobe command and response messages move small packets of I/O data between a master and its bit-strobed slaves.

5.5.5.2 Bit-strobe command message

The bit-strobe command sends one bit of output data to each slave.

The bit-strobe command message contains a bit string of 64 bits (8 bytes) of output data, one output bit for each possible MAC ID on the link.

A slave device may be designed to do one or all of the following:

– ignore the bit-strobe command;
– consume the bit-strobe command and its output data;
– consume the bit-strobe command as a trigger and ignore the output data.

Slaves shall default to ignoring the bit-strobe command until the bit-strobe connection is allocated.

A bit-strobe command message transmitted with no data in the CAN data field is interpreted as a receive_idle event by an application object. A bit-strobe command message that contains data is interpreted as a run event by an application object. The behaviour of an application object upon detection of either the receive_idle or run event is application object-specific. See the application object descriptions for more information concerning these events.

5.5.5.3 Bit-strobe response message

The bit-strobe response returns up to eight bytes of input data to the master from each slave.

A bit-strobe response message that contains no data and is configured to contain data indicates a master device no valid bit-strobe data event. The behaviour of the master upon detection of this event is implementation-specific.

5.5.5.4 Bit-strobe message characteristics

The master implements the communication resources associated with the bit-strobe command as a client transport class 0 connection to transmit the command and a set of server transport class 0 connection objects to receive the responses.

The slave implements a single server transport class 2 or 3 connection to receive the bit-strobe command and send the associated response.

5.5.6 Poll command/response messages

5.5.6.1 General

The poll command and response messages transfer I/O data between a master and its polled slaves.

5.5.6.2 Poll command message

The poll command sends up to 65535 bytes of output data (non-fragmented or fragmented) to the destination slave device.

A slave device is permitted to do one or all of the following:

– ignore the poll command if no poll connection is allocated;
– consume the poll command and its output data;
– consume the poll command as a trigger and ignore the output data.

Slaves shall default to ignoring the poll command until the poll connection is allocated.

A poll command message transmitted with no data in the CAN data field is interpreted as a receive_idle event by an application object. A poll command message that contains data is interpreted as a run event by an application object. The behaviour of an application object upon detection of the receive_idle or run event is application object-specific.

5.5.6.3 Poll response message

The poll response returns up to 65535 bytes (non-fragmented or fragmented) of input data to the master from the slave.

A poll response message that contains no data and is configured to contain data indicates a master device no valid poll data event. The master behaviour upon detection of this event is implementation-specific.

5.5.7 Change of state/cyclic connections

5.5.7.1 General

The predefined master/slave connection set supports change of state or cyclic data transfer between the master and the slave. This data transfer may be either acknowledged or unacknowledged.

The change of state/cyclic connection sets use connection instance 2 for master to slave data transfer and slave to master acknowledgement. Connection instance 4 is used for slave to master data transfer and master to slave acknowledgement. If a device does not support the poll and has no support for output data, connection instance 2 need not be created.

To keep the system behaviour consistent, the slave's change of state/cyclic connection (instance 4) shall have the consumed_connection_path attribute set to the acknowledgement handler object, and the instance of the acknowledgement handler object shall be 1.

Because the polled and change of state/cyclic connection sets share connection instance 2, the slave shall follow certain procedures based on the allocation request in order to ensure the correct behaviour. As described above, it is only when the change of state/cyclic allocation bit is on that connection instances 2 and 4 are created. Connection instance 4 produces from the default input path and consumes acknowledgements to instance 1 of the acknowledgement handler object. Connection instance 2 consumes to the default output path and produces a zero length acknowledgement. When the allocation request contains only the polled allocation bit, connection instance 2 consumes to the default output path and produces from the default input path.

If both the change of state/cyclic *and* the polled allocation bits are set, connection instance 2 shall behave as though only the polled allocation bit was set, and connection instance 4 shall continue to behave as described above. This is also the required behaviour if the master allocates the poll connection set in one message, and then the change of state/cyclic connection set in a following message.

To achieve unacknowledged data production, the acknowledgement suppression bit is set with either the change of state or cyclic bit in the allocation choice byte. Connection instance 2 is configured as a transport class 0 connection for master to slave data production. Connection instance 4 is configured as a transport class 0 connection for slave to master data production. When the poll bit is set in the same allocation choice, this causes connection instance 2 to be configured as the poll, while connection instance 4 continues to be configured as an unacknowledged change of state or cyclic connection.

5.5.7.2 Change of state/cyclic messages trigger acknowledgement

5.5.7.2.1 General

The change of state/cyclic messages move up to 65535 bytes of data between a master and slave using change of state or cyclic production triggers. Data production may be either acknowledged or unacknowledged.

The following subclauses describe:

– change of state/cyclic message (acknowledged);
– change of state/cyclic message (unacknowledged);
– change of state/cyclic message characteristics;
– change of state/cyclic example application.

5.5.7.2.2 Master’s change of state/cyclic message

The master’s change of state/cyclic sends up to 65535 bytes of data (non-fragmented or fragmented) to the destination slave device. Data production is triggered by either a change of state or transmission trigger time-out.

A change of state/cyclic message transmitted with no data in the CAN data field is interpreted as a receive_idle event by an application object. A change of state/cyclic message that contains data is interpreted as a run event by an application object. The behaviour of an application object upon detection of the run event is application object-specific.

5.5.7.2.3 Slave’s change of state/cyclic acknowledgement message

The slave’s change of state acknowledgement message returns up to 65535 bytes (non-fragmented or fragmented) of data to the master from the slave. By default, the acknowledgement message is zero length.

5.5.7.2.4 Slave’s change of state/cyclic message

The slave’s change of state/cyclic message sends up to 65535 bytes of data (non-fragmented or fragmented) to the master from the slave. Data production is triggered by either a change of state or transmitted trigger time-out.

A change of state/cyclic message that contains no data and is configured to contain data indicates a master device no valid change of state/cyclic data event. The master behaviour upon detection of this event is implementation-specific.

5.5.7.2.5 Master's change of state/cyclic acknowledgement message

The master's change of state/cyclic acknowledgement message returns up to 65535 bytes (non-fragmented or fragmented) of data to the slave from the master. By default, the acknowledgement message is zero length.

5.5.8 Group 2 only devices

To establish communications with a group 2 only device, a client shall allocate the predefined master/slave connection set. The request to allocate a group 2 only device is transmitted as a group 2 only unconnected explicit request. Instead of using the UCMM to establish explicit messaging connections, group 2 only devices receive and process group 2 only unconnected explicit request messages.

The only services that are valid when transmitted as group 2 only unconnected explicit request messages are:

– allocate_master/slave_connection_set message;
– release_master/slave_connection_set message.

These services are described in 5.3.3.5.2.

Responses to group 2 only unconnected explicit requests are returned by transmitting a group 2 message whose MAC ID component is set to the responding device's MAC ID (source MAC ID) and whose message ID is set to 3.

Group 2 only devices shall use the slave's explicit response message identifier field only for transmitting group 2 only unconnected response messages and predefined master/slave explicit messaging connection response messages.

If a group 2 only server receives a group 2 only unconnected request message that is not an allocate_master/slave_connection_set or release_master/slave_connection_set request, then an error response shall be returned whose general error code is set to 02, with the additional error code set to a DeviceNet object-specific value of 03 (see 5.3.3.6).

5.6 Physical layer

5.6.1 General

Table 41 shows the general physical layer specifications which shall be met in DeviceNet systems (see 9.2.6 for test specifications).

Table 41 – General physical layer characteristics

Characteristic	Specification
Bit rates	125 kbit/s, 250 kbit/s, 500 kbit/s
Maximum total length of trunk line and maximum cable length between any two devices	500 m at 125 kbit/s 250 m at 250 kbit/s 100 m at 500 kbit/s
Number of nodes supported by the transceiver	64 minimum
Signalling	In accordance with ISO 11898
Modulation	Baseband
Encoding	NRZ with bit stuffing
Coupling to transmission medium	DC coupled differential Tx/Rx
Isolation (between transceiver circuitry and CAN chip)	500 V d.c. Applies to isolated devices only
Differential input impedance typical (recessive state)	Shunt C = 5 pF Shunt R = 25 kΩ (power on)
Differential input impedance min. (recessive state)	Shunt C = 24 pF Shunt R = 20 kΩ (power on)
Voltage on the power conductors	11 V d.c. to 25 V d.c.
Maximum signal voltage range	–25 V d.c. to +18 V d.c. (CAN_H, CAN_L) [1]

[1] Voltages at CAN_H and CAN_L shall be referenced to the transceiver ground. The potential at the transceiver ground may be higher than the *U*– terminal by an amount equal to the voltage drop across a Schottky diode or equivalent. This voltage shall be 0,6 V maximum with respect to *U*–.

The physical layer, comprising the transceiver, connector, miswiring protection circuitry, voltage regulator, transmission medium and optional isolation, shall be as shown in figure 36. Testing of the robustness of the physical layer implementation within a device is specified in 9.2.9.

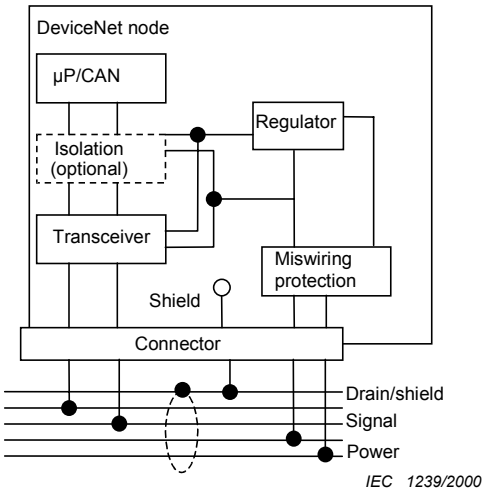


Figure 36 – Physical layer block diagram

5.6.2 Transceiver

A transceiver shall provide the transmission and reception of CAN signals to and from the link. The transceiver shall receive differential signals from the link and forward them to the CAN controller, and shall transmit differential signals from the CAN controller to the link.

To be compatible with the power system design, the transceiver CAN_H and CAN_L terminals shall support a minimum of ±5 V common mode operation, i.e. it shall tolerate ground differences of ±5 V.

The transceiver shall be continuously powered by the link.

The required characteristics for the transmitter and the receiver are given in table 42 and table 43 (see 9.2.7 for test specifications).

Table 42 – Transmitter characteristics

Transmitter characteristic	Specification
Differential output level (nominal)	2,0 V peak to peak
Differential output level (minimum) (measured at connector, 50 Ω load)	1,5 V peak to peak
Minimum dominant bus voltage at CAN_H	2,75 V [1)]
Maximum dominant bus voltage at CAN_H	4,5 V [1)]
Minimum dominant bus voltage at CAN_L	0,5 V [1)]
Maximum dominant bus voltage at CAN_L	2,0 V [1)]
Minimum recessive bus voltage at CAN_H and CAN_L	2,0 V [1)]
Maximum recessive bus voltage at CAN_H and CAN_L	3,0 V [1)]
Maximum transmitter delay (including isolation)	120 ns
Output short-circuit protection	Internally limited
[1)] Voltages at CAN_H and CAN_L shall be referenced to the transceiver ground. The potential at the transceiver ground may be higher than the *U*– terminal by an amount equal to the voltage drop across a Schottky diode or equivalent. This voltage shall be 0,6 V maximum with respect to *U*–.	

Table 43 – Receiver characteristics

Receiver characteristic	Specification
Differential input voltage dominant	0,95 V minimum
Differential input voltage recessive	0,45 V maximum
Hysteresis	150 mV typical
Maximum receiver delay (including isolation)	130 ns
Operating voltage range (CAN_H and CAN_L)	–5 to +10 V [1)]
[1)] Voltages at CAN_H and CAN_L shall be referenced to the transceiver ground. The potential at the transceiver ground may be higher than the *U*– terminal by an amount equal to the voltage drop across a Schottky diode or equivalent. This voltage shall be 0,6 V maximum with respect to *U*–.	

A device shall have an acknowledgement delay which is less than or equal to 302 ns. The acknowledgement delay comprises the propagation delays of the transmitter, receiver and CAN controller. Any combination of these delays is permitted provided that the total time is less than or equal to 302 ns and that the maximum transmitter and receiver delays given in table 42 and table 43 respectively are not exceeded.

NOTE The maximum transmitter delay time in table 42 is 120 ns and the maximum receiver delay time in table 43 is 130 ns. A maximum CAN controller delay time of 53 ns ensures that the acknowledgement delay does not exceed 302 ns.

See 9.2.8 for test specifications.

5.6.3 Grounding

To prevent ground loops, the link shall be grounded in only one location, preferably at the power supply. The physical layer circuitry in all devices shall be referenced to *U*–. A device shall not cause current to flow between *U*– and ground.

5.6.4 Isolation

5.6.4.1 General

Devices shall be either non-isolated devices or isolated devices.

NOTE Isolated devices and non-isolated devices may co-exist and communicate through CDIs.

5.6.4.2 Non-isolated devices

Within a device that contains a non-isolated physical layer, components which are ground referenced to *U*– may connect to other external devices. These external devices shall be ground isolated, and this requirement shall be stated in the manufacturer's documentation.

The shield connection on the DeviceNet connector should be connected through a parallel RC circuit (R = 1 MΩ, C = 0,01 μF (500 V)) to the device enclosure.

NOTE The best electromagnetic conformance may be achieved with the conductor kept very short along this path and with the enclosure being a closed structure of conductive material. If the device does not have such an enclosure, the shield pin of the connector may be left unconnected.

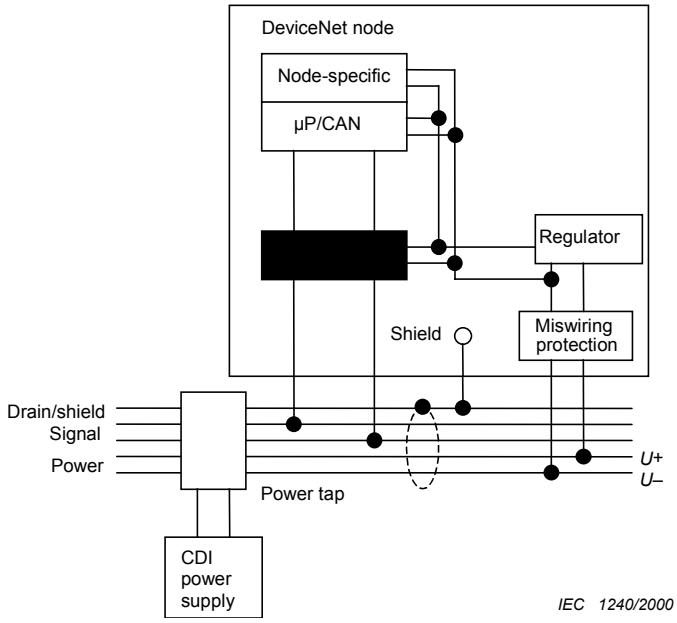


Figure 37 – Device containing a non-isolated physical layer

5.6.4.3 Isolated device

These devices shall obtain power from the link for the transceiver and isolation circuitry (see figure 38). Link power may be used for other circuitry provided that this link-powered circuitry is ground referenced to *U*– or is otherwise ground isolated.

For an isolated device, the CAN controller may still be active during a de-energized power line condition. Isolated devices shall be capable of sensing when their transceivers have become de-energized.

Within an isolated device, components which are ground referenced to *U*– may connect to other external devices through serial ports, parallel ports or I/O connections. These external devices shall be ground isolated and this requirement shall be stated in the manufacturer's documentation.

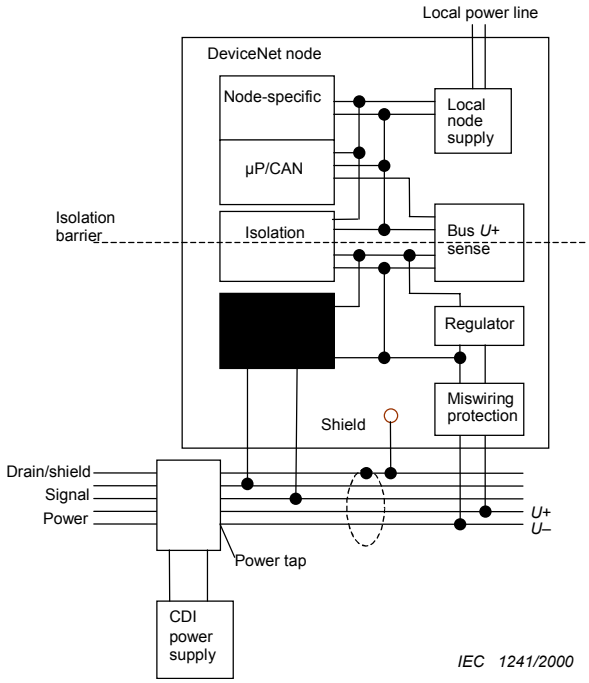


Figure 38 – Device containing an isolated physical layer

The shield connection of the link should be connected via a parallel RC circuit to the device enclosure.

5.6.5 Transmission medium

DeviceNet uses two twisted shielded conductor pairs within one cable. One of these pairs provides a differential communication medium and the other pair provides power to the devices.

DeviceNet provides two different types of cable: thick cable and thin cable. Thick cable provides higher current capability and allows communication over longer distances. Both thick and thin cable may be used for trunk lines and/or drop lines in any combination.

5.6.6 Topology

5.6.6.1 General

The DeviceNet medium shall have a linear topology. If used, drop lines may allow one or more nodes to be attached. Branching structures are only allowed on the drop line.

Terminating resistors shall be connected at each end of the trunk line. The cable distance between any two points in the cable system shall not exceed the maximum cable distance allowed for the bit rate.

5.6.6.2 Trunk lines

Either thick or thin cable may be used to construct trunk lines. The maximum cable distance with a mix of both thick and thin cable shall be calculated using the formulas below:

l_{thick} + 5 x l_{thin} = 500 m at 125 kbit/s
l_{thick} + 2,5 x l_{thin} = 250 m at 250 kbit/s
l_{thick} + l_{thin} = 100 m at 500 kbit/s

where l_{thick} is the length of thick cable and l_{thin} is the length of thin cable.

5.6.6.3 Drop lines

The drop line length is the cable distance measured from the tap on the trunk line to the transceiver of each device and shall not exceed 6 m. The total length of drop line cable allowable on the link depends upon the bit rate and shall not exceed the values specified in table 44.

Table 44 – Total drop line cable length

Bit rate kbits	**Cable length** m
125	156
250	78
500	39

5.6.7 Link power

5.6.7.1 Power configuration

The link power shall be supplied by a rated 24 V d.c. source and can support up to 8 A on any section of thick cable trunk line or up to 3 A on any section of thin cable trunk line. Multiple power supplies can be used.

5.6.7.2 Load limits

The maximum link current shall be determined using the information shown in table 45 (see 9.2.2 for test specifications).

Table 45 – Load limits

Characteristic	**Specification**
Maximum voltage drop on *U*– and *U*+	5 V each
Maximum thick cable trunk line current	8 A
Maximum thin cable trunk line current	3 A
Maximum drop line current range	0,75 A to 3,0 A [1)]
Voltage range at each node	11 V to 25 V
Operating current of each device [2)]	Specified by manufacturer

[1)] The maximum drop line current depends upon the length of the drop (see below).

[2)] The operating current represents the average current drawn from the link. The peak operating current shall be specified if it exceeds the average current by more than 10 %.

The maximum drop line current is also constrained by the following equation:

$$i = 4{,}5 / l$$

where

i is the maximum allowable drop line current (A);

l is the drop length (m).

6 Product information

In accordance with IEC 62026-1.

7 Normal service, mounting and transport conditions

7.1 Normal service conditions

7.1.1 General

Components of a DeviceNet CDI shall be capable of operating under the following conditions.

NOTE If the conditions for operation differ from those given in this part, the user should state the deviation from the standard conditions and consult the manufacturer on the suitability for use under such conditions.

7.1.2 Ambient air temperature

7.1.2.1 Thick cable

The cable shall operate normally within an ambient temperature range of –20 °C to +60 °C when carrying a current of 8 A. This current rating shall be derated linearly to zero at +80 °C.

7.1.2.2 Thin cable

The cable shall operate normally within an ambient temperature range of –20 °C to +70 °C when carrying a current of 1,5 A. This current rating shall be derated linearly to zero at +80 °C.

7.1.2.3 Device taps

Device taps shall operate normally within an ambient temperature range of –40 °C to +70 °C when carrying full current. This current rating shall be derated linearly to zero at +80 °C. The maximum continuous current on power conductors is 3 A for microconnectors and 8 A for other connectors, unless otherwise specified.

7.1.2.4 Power taps

Power taps shall operate normally within an ambient temperature range of –40 °C to +70 °C when carrying full current. This current rating shall be derated linearly to zero at +80 °C.

7.1.2.5 Other CDI components

All other components of a DeviceNet CDI shall operate between the ambient temperatures of –25 °C and +70 °C if not otherwise defined, for example in conjunction with a specific actuator or sensor type. The operating characteristics shall be maintained over the permissible range of ambient temperature.

7.1.3 Altitude

DeviceNet components shall be capable of operating at altitudes in accordance with IEC 62026-1.

7.1.4 Climatic conditions

7.1.4.1 Humidity

DeviceNet components shall be capable of operating at 40 °C, with the relative humidity of the air not exceeding 95 %.

7.1.4.2 Pollution degree

DeviceNet components shall be capable of operating in polluted conditions in accordance with IEC 62026-1.

7.2 Conditions during transport and storage

A special agreement shall be made between the user and the manufacturer if the conditions during transport and storage differ from the following:

– humidity: relative humidity of the air not exceeding 95 % at 40 °C;
– storage temperature: –40 °C to +85 °C

7.3 Mounting

DeviceNet components shall be mounted in accordance with IEC 62026-1.

8 Constructional and performance requirements

8.1 Indicators and configuration switches

8.1.1 Status indicators

8.1.1.1 General

Devices may have the following status indicators:

– one module status indicator and one CDI status indicator, or one combined module/CDI status indicator;
– I/O status indicator.

Any other indicators shall be clearly distinguishable from those defined above.

8.1.1.2 Module status indicator

This shall be a bicolour (green/red) indicator and shall indicate whether or not the DeviceNet circuitry is powered and operating correctly. The indicator states shall be as specified in table 46.

Table 46 – Module status indicator

Indicator status	Meaning
Off	Not powered
Green	Operating correctly
Flashing green	Missing, incomplete or incorrect configuration
Flashing red	Recoverable fault
Red	Unrecoverable fault
Flashing red-green	Undergoing self-test
NOTE Indicator flash rates are given in 8.1.1.8.	

8.1.1.3 CDI status indicator

This shall be a bicolour (green/red) indicator and shall indicate the status of the communication link as specified in table 47.

Table 47 – CDI status indicator

Indicator status	Meaning
Off	The duplicate MAC ID detection test has not been completed or the DeviceNet circuitry is not powered
Flashing green	Device is on-line but has no connections established
Green	Device is on-line and has connections established
Flashing red	One or more I/O connections have timed-out
Red	The device has detected an error and cannot communicate on the link
NOTE Indicator flash rates are given in 8.1.1.8.	

8.1.1.4 Module and CDI status indicators at power-up

The following indicator test sequence shall be performed at power-up:

– CDI status indicator OFF;
– module status indicator ON green for 0,25 s ± 0,1 s;
– module status indicator ON red for 0,25 s ± 0,1 s;
– module status indicator ON green;
– CDI status indicator ON green for 0,25 s ± 0,1 s;
– CDI status indicator ON red for 0,25 s ± 0,1 s;
– CDI status indicator OFF;
– both indicators assume states according to table 46 and table 47.

8.1.1.5 Combined module/CDI status indicator

This shall be a bicolour (green/red) indicator and shall provide limited device and communication status information.

The combined module/CDI status indicator states shall be as specified in table 48.

Table 48 – Combined module/CDI status indicator

Indicator status	Meaning
Off	Device is not on-line: – the device may not have completed the duplicate MAC ID test – the device may not be powered
Green	The device is operating in a normal condition and the device is on-line with connections in the established state
Flashing green	The device is operating in a normal condition and either the device is on-line with no connections in the established state or configuration is missing, incomplete or incorrect
Flashing red	Recoverable fault and/or one or more I/O connections are in the timed-out state
Red	The device has an unrecoverable fault that has rendered it incapable of communicating on the link
NOTE Indicator flash rates are given in 8.1.1.8.	

8.1.1.6 Combined module/CDI status indicator at power-up

The following indicator test sequence shall be performed at power-up:

– combined module/CDI status indicator ON green for 0,25 s ± 0,1 s;
– combined module/CDI indicator ON red for 0,25 s ± 0,1 s;
– combined module/CDI indicator OFF;
– indicator assumes state according to table 48.

8.1.1.7 I/O status indicator

This shall be a bicolour (green/red) indicator and shall provide information concerning the states of inputs and/or outputs.

The I/O status indicator states shall be as specified in table 49.

Table 49 – I/O status indicator

Indicator status	Meaning
Off	All outputs are inactive All inputs are inactive
Flashing green	One or more outputs are idle and no outputs are faulted
Green	One or more outputs are active and under control, no outputs are faulted One or more inputs are active and producing data, no inputs are faulted
Flashing red	One or more outputs are faulted One or more inputs are faulted
Red	One or more outputs are forced OFF (may be an unrecoverable fault) One or more inputs have an unrecoverable fault
NOTE Indicator flash rates are given in 8.1.1.8.	

8.1.1.8 Indicator flash rate

Unless otherwise specified in this part, the flash rate of an indicator shall be 1 flash per second ± 0,5 s. An indicator shall be ON for 0,5 s ± 0,25 s and OFF for 0,5 s ± 0,25 s.

8.1.2 DeviceNet bit rate switches

If switches are used to set the DeviceNet bit rate, they shall be encoded as shown in table 50.

Table 50 – DeviceNet bit rate switch encoding

Bit rate kbit/s	**Switch setting**
125	0
250	1
500	2

8.1.3 Indicator and switch marking

Indicators and switches shall be marked with either their full names or their abbreviated names, as specified in table 51.

Table 51 – Indicator and switch marking

Description	**Full name**	**Abbreviated name**
Module status indicator	Module status	MS
CDI status indicator	Network status	NS
Combined module/CDI status indicator	Module/network status or Mod/net status	MNS
I/O status indicator	I/O status or I/O	IO
MAC ID switches	Node address	NA
Bit rate switches	Data rate	DR

8.2 DeviceNet cable

The physical configuration for both thick and thin cables shall be as shown in figure 39.

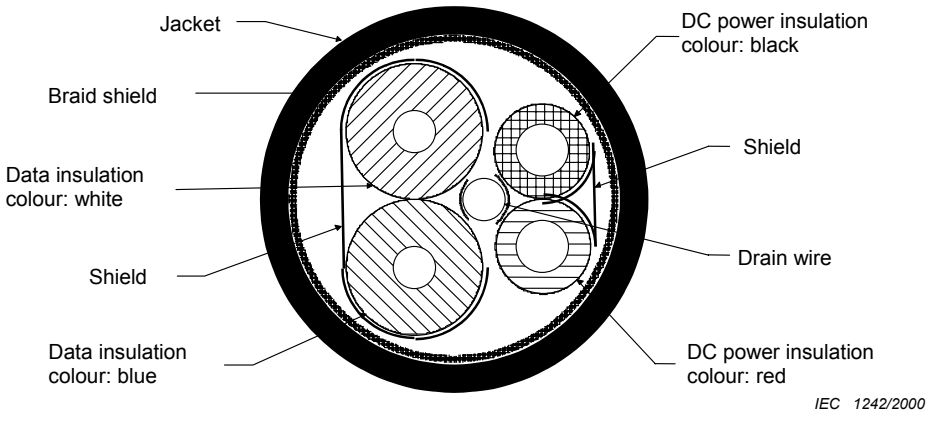


Figure 39 – Physical configuration of thick and thin cable

The cable shall be in accordance with the specifications given in table 52, table 53 and table 54.

Table 52 – Cable: data pair specification

Characteristic	Thick cable specification	Thin cable specification
Conductor pair size	0,823 mm^2 copper (individually tinned)	0,205 mm^2 copper (individually tinned)
Colours	Blue, white	Blue, white
Nominal pair twist	10 / m	16 / m
Shield over pair	98 % coverage	98 % coverage
Impedance	120 Ω ±10 % at 1 MHz	120 Ω ± 10 % at 1 MHz
Maximum propagation delay	4,46 ns/m	4,46 ns/m
Capacitance between conductors	39 pF/m at 1 MHz (nominal)	39 pF/m at 1 MHz (nominal)
Nominal capacitance between one conductor and another conductor connected to shield	79 pF/m at 1 MHz	79 pF/m at 1 MHz
Maximum capacitive imbalance	2,0 pF/m at 1 MHz	2,0 pF/m at 1 MHz
Resistance at +20 °C	Nominal 18 Ω / 1 000 m Maximum 23 Ω / 1 000 m	Nominal 69 Ω / 1 000 m Maximum 92 Ω / 1 000 m
Maximum attenuation	0,43 dB / 100 m at 125 kHz 0,82 dB / 100 m at 500 kHz 1,2 dB / 100 m at 1 MHz	0,95 dB / 100 m at 125 kHz 1,6 dB / 100 m at 500 kHz 2,3 dB / 100 m at 1 MHz

Table 53 – Cable: d.c. power pair specification

Physical characteristics	Thick cable specification	Thin cable specification
Conductor pair size	1,65 mm^2 copper (individually tinned)	0,326 mm^2 (individually tinned)
Colours	Red, black	Red, black
Nominal pair twist	10 / m	16 / m
Shield over pair	98 % coverage	98 % coverage
Resistance at +20 °C	Nominal 11 Ω / 1 000 m Maximum 12 Ω / 1 000 m	Nominal 45,9 Ω / 1 000 m Maximum 57,4 Ω / 1 000 m

Table 54 – Cable: general specifications

Characteristics	Thick cable specification	Thin cable specification
Two shielded pairs	Common axis with drain wire in centre	Common axis with drain wire in centre
Overall braid shield	65 % coverage, 0,126 mm^2 Cu braid (individually tinned)	65 % coverage, 0,126 mm^2 Cu braid (individually tinned)
Drain wire	0,823 mm^2 copper (individually tinned)	0,326 mm^2 copper (individually tinned)
Resistance at +20 °C (shields and drain wire)	5,74 Ω / 1 000 m	10,5 Ω / 1 000 m

8.3 Terminating resistors

A 121 Ω, 1 %, 0,25 W metal film resistor shall be connected at each end of the trunk line.

Terminating resistors shall not be included in devices.

8.4 Connectors

8.4.1 General specifications

All connectors shall have five terminals: a signal pair, a power pair and a shield. Connectors shall be either the open or sealed type.

Open connectors shall comply with the specifications given in table 55.

Table 55 – Open connector general specifications

Connector style	Specification
Pluggable	5 pin open style male (pin) contacts with mechanical locking to prevent reverse insertion
Hard wired	Includes direct soldering, crimping, screw terminal blocks, barrier strips or other similar attachment methods Hard wired connection shall enable a device to be removed without severing the trunk. The attachment of devices using these methods shall not be attempted while link power is applied

Sealed connectors shall be protected to IP67 (see IEC 60529) and shall comply with the specifications given in table 56.

Table 56 – Sealed connector general specifications

Connector style	Specification
Male mini-connector	5 pin “mini” style male (pin) contacts with 7/8-16 UN-2A male (outside) connection thread. Shall meet ANSI/B93.55M design and mating requirements
Female mini-connector	5 pin “mini” style female (socket) contacts with 7/8-16 UN-2B female (inside) connection thread. Shall meet ANSI/B93.55M design and mating requirements
Male micro-connector	See IEC 60947-5-2
Female micro-connector	See IEC 60947-5-2

8.4.2 Contact and electrical specifications

Connectors shall comply with the specifications given in table 57 and table 58.

Table 57 – Contact specifications

Physical characteristics	Specification
Wiping contact plating requirements	0,76 μm gold minimum over 1,3 μm nickel minimum or 0,13 μm gold minimum over 0,51 μm palladium-nickel minimum over 1,3 μm nickel. All gold shall be 24 carat
Wiping contact life	1 000 insertions / extractions
NOTE This requirement applies to contacts that may be subjected to multiple engagements and not to hard wired semi-permanent connections such as screw terminals.	

Table 58 – Electrical specifications

Electrical characteristics	Specification
Operating voltage	25 V d.c. minimum
Contact current rating	Connector contacts for use with thick cable shall be rated at 8 A minimum. Connector contacts for use with thin cable shall be rated at 3 A minimum Power supply contact current ratings shall be equal to or greater than the power supply current rating
Contact resistance	Initial: less than 1 mΩ. Maximum: 5 mΩ throughout life

8.4.3 Contact arrangement of device-mounted connectors

All device-mounted connectors shall have male contacts and shall be arranged as shown in table 59.

Table 59 – Connector contact arrangement

Function	Wire colour	Pluggable and hard wired connector contact numbers	Sealed mini and micro style connector contact numbers
U+	Red	5	2
U–	Black	1	3
CAN_H	White	4	4
CAN_L	Blue	2	5
Shield	Bare	3	1

8.5 Device taps and power taps

8.5.1 Device taps

Device taps provide points of attachment onto the trunk line. Devices may be connected to the link either directly to the device tap or with a drop line. Device taps shall also allow the removal of a device without disrupting the CDI operation.

Device taps shall have a minimum voltage rating of 25 V d.c. and shall comply with the specifications given in table 60 and table 61.

Table 60 – Internal pass-through conductor specifications

Conductor description	Specification
Drain wire conductor	100 mm maximum length of conductor Maximum resistance 2,3 mΩ
Power conductors *U*+ and *U*–	100 mm maximum length of conductor Maximum resistance 1,2 mΩ. Rated current 8 A
Signal conductors CAN_H and CAN_L	100 mm maximum length of conductor Maximum resistance 2,3 mΩ

Table 61 – Internal drop conductor specifications

Conductor description	Specification
Drain wire conductor	180 mm maximum length and 10 mΩ maximum resistance, both measured between the trunk line tap connector and any port connection
Power conductors *U*+ and *U*–	180 mm maximum length measured between the trunk line tap connector and any port connection. Maximum resistance 10 mΩ for conductors rated up to 3 A, 4 mΩ otherwise, both measured between the trunk line tap connector and any port connection
Signal conductors CAN_H and CAN_L	180 mm maximum length and 10 mΩ maximum resistance, both measured between the trunk line tap connector and any port connection

8.5.2 Power taps

A power tap connects a power supply to the trunk line. When connected to the link, a power tap shall provide continuous connection for the signal, drain and *U*– wires. A power tap may also provide:

– overcurrent protection in each direction from the tap;
– power supply protection when multiple power supplies are used;
– a connection to the shield/drain wire for grounding the link.

DeviceNet power taps shall have a minimum voltage rating of 25 V d.c. and shall comply with the specifications given in table 62 and table 63.

Table 62 – Internal pass-through conductor specifications

Conductor description	Specification
Drain wire conductor	180 mm maximum length of conductor Maximum resistance 4,1 mΩ
U– power conductor	180 mm maximum length of conductor Maximum resistance 2,1 mΩ. Rated current 8 A
Signal conductors CAN_H and CAN_L	180 mm maximum length of conductor Maximum resistance 4,1 mΩ

Table 63 – Internal power drop conductor specifications

Conductor description	Specification
Drain wire conductor to ground terminal	180 mm maximum length and 2,1 mΩ maximum resistance, both measured between any tap connector and the ground terminal
Power conductors *U*+ and *U*–	300 mm maximum length and 3,6 mΩ maximum resistance, both measured between any tap connector and the power supply port connection. Wires shall be rated to carry the operating current

Power tap connectors (except the power supply connector) shall meet the requirements given in 8.4.

8.6 Link powered devices

Devices may draw power from the link. Such devices shall use a voltage regulator with an input voltage between 11 V d.c. and 25 V d.c., and incorporate transient protection and filtering.

The voltage regulator shall comply with the specifications given in table 64.

Table 64 – Voltage regulator specifications

Specification	Parameter
Input voltage range	11 V d.c. to 25 V d.c.
Isolation (if required)	500 V
Power ON delay	Linear regulators: none Switch mode regulators: <100 mA 2 ms to 10 ms 0,1 A to 0,5 A 5 ms to 15 ms 0,5 A to 1 A 10 ms to 20 ms 1 A to 2 A 15 ms to 30 ms >2 A 20 ms to 40 ms
Output short-circuit protection	Current limit
Reverse polarity protection	Rectifier in ground path [1)]
[1)] If the rectifier is used to power the transceiver, it shall have a forward voltage no greater than 0,6 V.	

8.7 Miswiring protection

Devices shall be capable of sustaining misconnection without suffering damage, under the following conditions:

– *U*+ and *U*– conductors interchanged;
– connection of the drain wire to any other conductor;
– connection of CAN_H and/or CAN_L to a voltage not exceeding the range –25 V d.c. to +18 V d.c.

See 9.2.4 and 9.2.5 for test specifications.

8.8 Power supplies

Power supplies which are connected to the link shall comply with the specifications given in table 65 (see 9.2.1 for test specifications).

Table 65 – DeviceNet power supply specifications

Specification	Parameter
Nominal voltage at +20 °C	24 V d.c. ± 1 % or adjustable to 0,2 %
Line regulation	0,3 % max. over the range specified by the manufacturer
Load regulation	0,3 % max.
Temperature coefficient	0,03 % per K max.
Output ripple	250 mV peak to peak
Load capacitance capability	7 000 μF max.
Overcurrent protection	100 % to 125 % of rated current
Output voltage rise time (with full load)	250 ms max. to 95 % of final value
Power ON overshoot	0,2 % max.
Stability	0 to 100 % load (all conditions)
Isolation	Output isolated from input voltage and chassis ground

8.9 Electromagnetic compatibility (EMC)

8.9.1 General

All immunity and emission tests are type tests and shall be carried out under representative conditions, both operational and environmental, using the recommended wiring practices and including all equipment necessary for communication and data transfer on the DeviceNet cable (see 9.2.10 for test specifications).

This requirement shall be met by the use of two devices with ongoing I/O communication and one power supply.

8.9.2 Immunity

8.9.2.1 Performance criteria

The test results are specified using the following performance criteria:

– **criterion A:** no degradation of performance beyond specified limits is allowed when the apparatus is used as intended, see table 66;

– **criterion B:** no change of actual operating state or stored data is allowed. During the test, degradation of performance is allowed. No degradation of performance or loss of function beyond specified limits is allowed after the test when the apparatus is used as intended, see table 66.

Table 66 – Immunity performance criteria

Function type	Criterion A	Criterion B
Masters (processors and adapters)	Program loss Memory faults I/O reset Data table corruption	Program loss Memory faults I/O reset Data table corruption
Any module	Unexpected operation Lockup Operator intervention Damage	Unexpected operation Lockup Operator intervention Damage
External communications	Node off-line	Node off-line
Internal communications: – Radiated, conducted – Fast transient – ESD – Surge	> 1 error bit set / 10 transfers	> 1 error bit set / 10 transfers Lockup Lockup

8.9.2.2 Electrostatic discharge (ESD) immunity

In accordance with IEC 61000-4-2, 10 discharges of each polarity shall be applied as follows:

– a test voltage of ±8 kV shall be applied by the air gap discharge method to non-metallic device enclosures;
– a test voltage of ±4 kV shall be applied by the contact discharge method to metallic device enclosures.

Performance criterion B applies (see 8.9.2.1).

8.9.2.3 Radiated radio-frequency electromagnetic field immunity

In accordance with IEC 61000-4-3:

– 10 V/m over the frequency range 80 MHz to 1 000 MHz, amplitude modulated.

Performance criterion A applies (see 8.9.2.1).

8.9.2.4 Electrical fast transient/burst immunity

In accordance with IEC 61000-4-4:

– a maximum test voltage of ±1 kV at 5 kHz shall be applied to cables that contain the CDI communication medium;
– a maximum test voltage of ±2 kV at 5 kHz shall be applied to all other cables and ports.

Performance criterion B applies (see 8.9.2.1).

8.9.2.5 Surge immunity

In accordance with IEC 61000-4-5:

– five surges at a maximum of ±2 kV shall be applied between a.c. mains line and earth;
– five surges at a maximum of ±1 kV shall be applied between a.c. mains lines.

Performance criterion B applies (see 8.9.2.1).

8.9.2.6 Conducted radio-frequency disturbance immunity

In accordance with IEC 61000-4-6:

– 10 V r.m.s. over the frequency range 150 kHz to 80 MHz, amplitude modulated.

Performance criterion A applies (see 8.9.2.1).

8.9.2.7 Voltage dips and interruptions

Conformity of the power supply to the specified limits given in table 65 eliminates the need for any further testing.

8.9.3 Emissions

8.9.3.1 Radiated emissions

In accordance with CISPR 11, group 1, class A.

8.9.3.2 Conducted emissions

In accordance with CISPR 11, group 1, class A.

9 Tests

9.1 General

This clause specifies type tests for electrical and logical requirements. Tests are divided into two parts:

– electrical and EMC testing;
– logical testing (behaviour of a device on DeviceNet).

NOTE If DeviceNet specifications are implemented as an integral part of a product, some logical tests may depend on the behaviour of the product itself. Conformance to this part of the standard does not necessarily mean conformance to a specific standard of the whole product in which DeviceNet is integrated. A test of specific applications of DeviceNet functions is outside the scope of this part of the standard.

The tests applicable to a specific EUT shall be performed in the sequence indicated.

9.2 Electrical and EMC testing

9.2.1 Test of the DeviceNet power supply

9.2.1.1 Test purpose

The following tests verify the power supply requirements that are specific to DeviceNet.

9.2.1.2 Power supply output voltage rise time

9.2.1.2.1 Test circuit

The test circuit shall be as shown in figure 40. Select the load resistor (R) to ensure that the power supply operates at rated current.

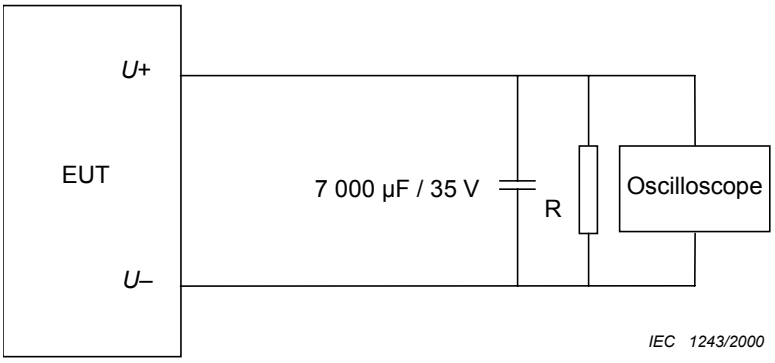


Figure 40 – Power supply rise time test circuit

9.2.1.2.2 Test procedure

The oscilloscope connected across the load resistor shall be set to 24 V, 500 ms full scale. The EUT shall be switched on and the rise time from the start of the voltage rise to 95 % of the power supply final voltage shall be recorded.

9.2.1.2.3 Criteria for compliance

The rise time shall be less than or equal to 250 ms (see table 65).

9.2.1.3 Power supply ripple

9.2.1.3.1 Test circuit

The test circuit shall be as shown in figure 40, with the capacitor disconnected.

9.2.1.3.2 Test procedure

The power supply shall be switched on and the a.c. peak-to-peak ripple of the power supply output voltage measured using the oscilloscope.

9.2.1.3.3 Criteria for compliance

In order to meet the power supply requirements, the peak-to-peak ripple shall be less than or equal to 250 mV (see table 65).

9.2.2 Device peak current consumption

9.2.2.1 Test circuit

The test circuit shall be as shown in figure 41.

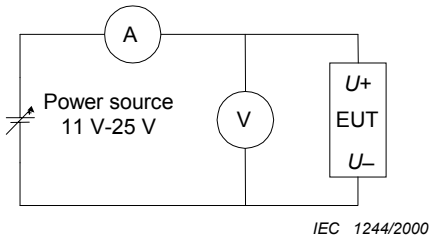


Figure 41 – Current consumption test circuit

9.2.2.2 Test procedure

To determine the operating state that results in maximum current consumption from the link. The EUT shall be operated in this state. If current fluctuations occur, the peak current drawn from the link shall be recorded.

The tests shall be performed at the upper and lower limits of the voltage range specified in 5.6.7.2.

9.2.2.3 Criteria for compliance

To determine the applicable current limit by inspection of the device and/or the manufacturer's documentation. The current readings obtained shall be in accordance with 5.6.7.2 and shall be less than or equal to 8 A.

9.2.3 Power ON behaviour

9.2.3.1 Test purpose

The purpose of this test is to determine that the first transmitted signal is a valid duplicate MAC ID message under the following conditions:

– when added to an existing working CDI;
– when the power is cycled on the CDI.

9.2.3.2 Test circuit

The test circuit shall be as shown in figure 42.

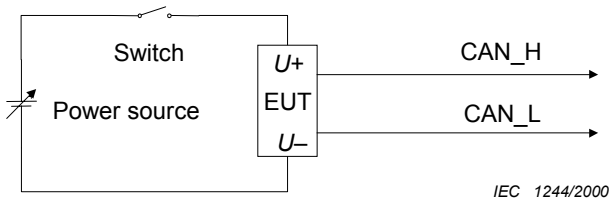


Figure 42 – Power ON test circuit

9.2.3.3 Test procedure

The switch shall be closed and the CAN_H and CAN_L signal lines shall be monitored.

9.2.3.4 Criteria for compliance

The first transmitted signal shall be a valid duplicate MAC ID request.

9.2.4 Reverse connection of *U*+ and *U*–

9.2.4.1 Test purpose

The purpose of this test is to verify compliance with the requirements for miswiring protection.

9.2.4.2 Test circuit

The test circuit shall be as shown in figure 43.

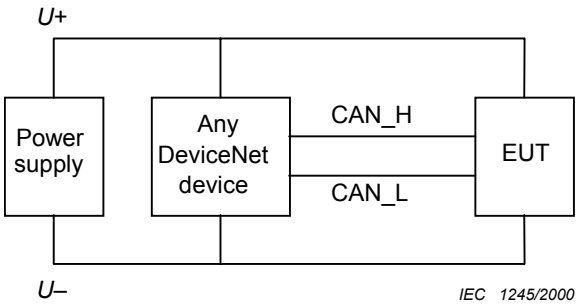


Figure 43 – Test circuit for reversal of *U*+ and *U*–, and also *U*– interruption

9.2.4.3 Test procedure

The *U*+ terminal of the EUT shall be connected to the *U*– of the power supply and link, and the *U*– terminal of the EUT shall be connected to the *U*+ of the power supply and link. CAN_H and CAN_L shall be monitored.

9.2.4.4 Criteria for compliance

It shall be verified that the CAN_H and CAN_L signals remain within the limits specified in table 42 and table 43.

9.2.5 Disconnection of *U*–

9.2.5.1 Test purpose

The purpose of this test is to verify compliance with the requirements for miswiring protection.

9.2.5.2 Test circuit

The test circuit shall be as shown in figure 43.

9.2.5.3 Test procedure

The *U*– connection shall be disconnected at the EUT. CAN_H and CAN_L shall be monitored.

9.2.5.4 Criteria for compliance

It shall be verified that the CAN_H and CAN_L signals remain within the limits specified in table 42 and table 43.

9.2.6 Differential input impedance test

9.2.6.1 Test purpose

The purpose of this test is to verify that the input impedance of the EUT meets the requirements of the physical layer.

9.2.6.2 Test circuit

The test circuit shall be as shown in figure 44.

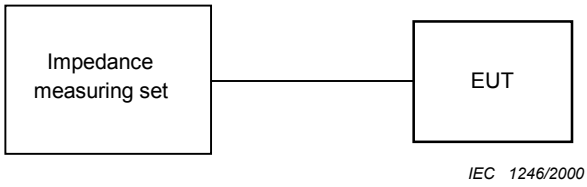


Figure 44 – Differential impedance test circuit

9.2.6.3 Test procedure

Power shall be applied to the EUT. The transceiver of the EUT shall be disabled in such a way that the impedance is not affected. The input impedance of the EUT between CAN_H and CAN_L shall then be measured at a frequency of 100 kHz ± 1 kHz.

9.2.6.4 Criteria for compliance

The input impedance of the EUT between CAN_H and CAN_L shall not exceed the values specified in table 41.

9.2.7 Transmit levels

9.2.7.1 Test purpose

The purpose of this test is to determine whether the values of CAN_H and CAN_L with respect to *U*– under simulated worst case impedance conditions are within the limits specified as part of the physical layer requirements.

9.2.7.2 Test circuit

The test circuit shall be as shown in figure 45.

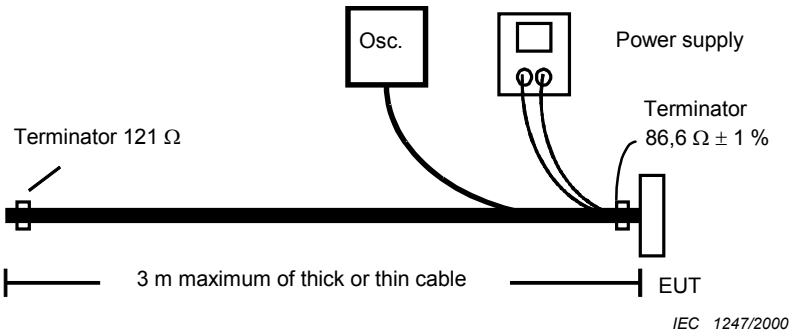


Figure 45 – Transmit level test set-up

9.2.7.3 Test procedure

For this test, the EUT shall be transmitting. With no other device on the link, the EUT will automatically start sending duplicate MAC ID request messages after completing its power-up sequence. The actual message content from the EUT shall be observed on the oscilloscope. The following values shall be recorded (see figure 46):

– recessive CAN_L voltage with respect to *U*–;
– recessive CAN_H voltage with respect to *U*–;
– dominant CAN_L voltage with respect to *U*–;
– dominant CAN_H voltage with respect to *U*–;
– differential output level.

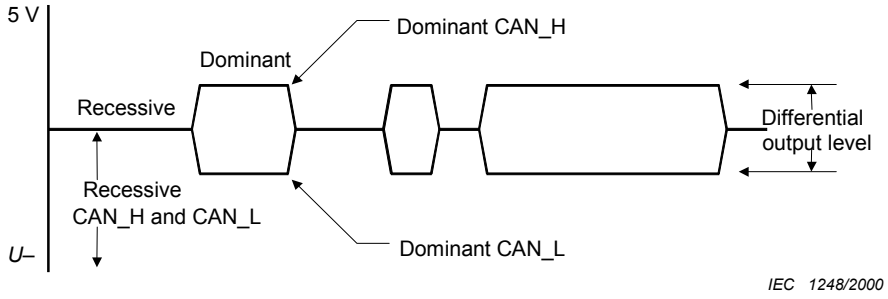


Figure 46 – Transmit levels

9.2.7.4 Criteria for compliance

The values shall be in accordance with those specified in table 42.

9.2.8 Acknowledgement delay

9.2.8.1 Test purpose

The purpose of this test is to check that the acknowledgement delay is within the limits specified as part of the physical layer requirements.

9.2.8.2 Test circuit

The test circuit shall be as shown in figure 47.

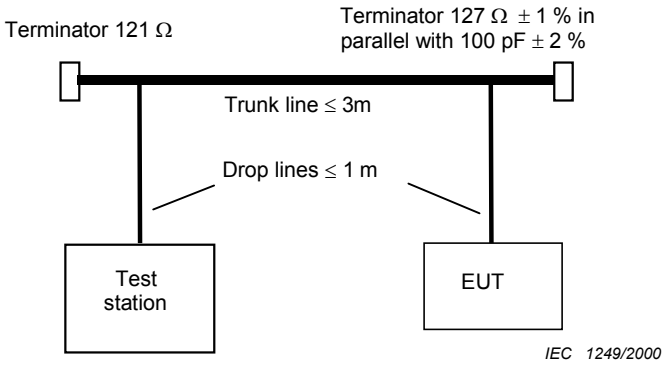


Figure 47 – Timing test set-up

9.2.8.3 Test procedure

The EUT and the test station shall be set to the highest bit rate supported by the EUT. The test station shall repetitively send a get_attribute_single request to the EUT without opening a messaging connection. This ensures that the EUT sends no messages other than the acknowledgement bit. An oscilloscope shall be used to measure the acknowledgement response time at the EUT. This is the time from the falling edge of the last bit sent by the test station to the rising edge of the acknowledgement bit sent by the EUT (see figure 48).

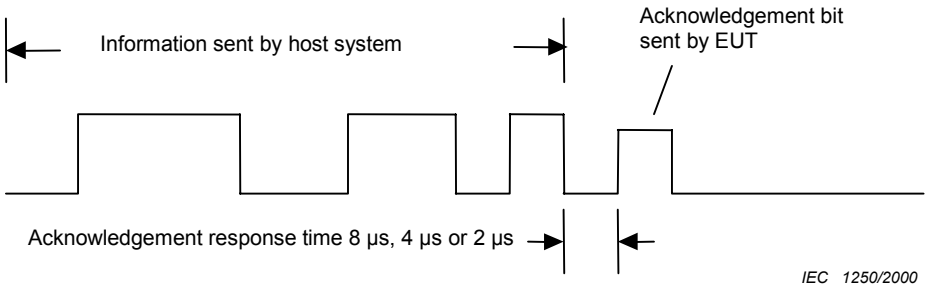


Figure 48 – Timing

9.2.8.4 Criteria for compliance

Depending on the bit rate used, the following values shall be subtracted from the response times measured:

125 kbit/s 8 µs

250 kbit/s 4 µs

500 kbit/s 2 µs

The resultant device acknowledgement delay shall be less than or equal to the value specified in 5.6.2.

9.2.9 CDI test

9.2.9.1 Test purpose

The purpose of this test is to determine whether the missing acknowledgement bits and bus-off conditions under worst case conditions are within the limits specified within the manufacturer's documentation.

9.2.9.2 Test circuit

The test circuit shall be as shown in figure 49:

– the system shall be run at the maximum bit rate supported by the EUT;
– the cable system shall be constructed of the maximum trunk line length of thick cable suitable for this bit rate;
– the maximum cumulative drop line shall be constructed of the maximum thin cable drop line length suitable for this bit rate;
– 62 devices or 62 device equivalents shall be used to load the CDI near the EUT;

NOTE A device equivalent is the minimum differential input impedance as defined in table 41.

– a power supply shall be used that meets the specifications described in table 65 (minimum current capacity 4 A);
– a worst case link power load shall be connected adjacent to the EUT. This load shall cause the *U*– line to develop a $5\ ^{0}_{-0,1}$ V drop from the power supply to the EUT;
– a test station shall be used that is capable of both producing valid communication traffic to the EUT and monitoring all communication traffic.

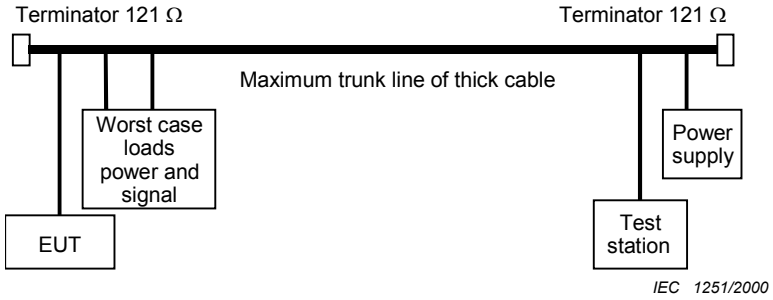


Figure 49 – CDI test configuration

9.2.9.3 Test procedure

Communications shall be established between the test station and the EUT. Any missing acknowledgement bits or bus-off conditions shall be recorded.

9.2.9.4 Criteria for compliance

The recorded missing acknowledgement bits and bus-off conditions shall be as specified by the manufacturer of the EUT.

9.2.10 Electromagnetic compatibility testing

9.2.10.1 General

The test circuit shall be as shown in figure 49:

– the system shall be run at the maximum bit rate supported by the EUT;
– the trunk line shall be constructed of thick cable;

– a power supply shall be used that meets the specifications described in table 65 (minimum current capacity 4 A);
– a test station shall be used that is capable of both producing valid communication traffic to the EUT and monitoring all communication traffic.

Unless otherwise noted, the tests shall be carried out at an ambient temperature of +23 °C ± 5 °C.

The EUT shall be mounted in free air and shall be connected to the DeviceNet CDI according to the manufacturer's instructions and supplied with its rated voltage.

9.2.10.2 Immunity

9.2.10.2.1 Electrostatic discharge (ESD) immunity

This test shall be performed in accordance with IEC 61000-4-2 and 8.9.2.2.

The trunk line length shall be as short as possible. The EUT shall be directly connected to the trunk line. If this is not possible, then the drop line shall not exceed 1 m.

9.2.10.2.2 Radiated radio-frequency electromagnetic field immunity

This test shall be performed in accordance with IEC 61000-4-3 and 8.9.2.3.

The trunk line length shall be the maximum allowable (see 5.6.6.2). The EUT shall be connected to the trunk line using the maximum length drop line allowable (see 5.6.6.3).

9.2.10.2.3 Electrical fast transient/burst immunity

This test shall be performed in accordance with IEC 61000-4-4 and 8.9.2.4.

The trunk line length shall be the maximum allowable (see 5.6.6.2). The EUT shall be directly connected to the trunk line. If this is not possible, then the drop line shall not exceed 1 m.

9.2.10.2.4 Surge immunity

This test shall be performed in accordance with IEC 61000-4-5 and 8.9.2.5.

The trunk line length shall be the maximum allowable (see 5.6.6.2). The EUT shall be directly connected to the trunk line. If this is not possible, then the drop line shall not exceed 1 m.

9.2.10.2.5 Conducted radio-frequency disturbance immunity

This test shall be performed in accordance with IEC 61000-4-6 and 8.9.2.6.

The trunk line length shall be the maximum allowable (see 5.6.6.2). The EUT shall be directly connected to the trunk line. If this is not possible, then the drop line shall not exceed 1 m.

9.2.10.3 Emissions

9.2.10.3.1 Radiated emissions

This test shall be performed in accordance with CISPR 11, group 1, class A, and 8.9.3.1.

The trunk line length shall be the maximum allowable (see 5.6.6.2). The EUT shall be connected to the trunk line using the maximum length drop line allowable (see 5.6.6.3).

9.2.10.3.2 Conducted emissions

This test shall be performed in accordance with CISPR 11, group 1, class A, and 8.9.3.2.

The trunk line length shall be the minimum required for the test fixture and shall not exceed the maximum length specified in 5.6.6.2. The EUT shall be connected to the trunk line using the maximum length drop line allowable (see 5.6.6.3).

9.3 Logical testing

9.3.1 General

Tests shall only be performed on nodes that support the particular functionality being tested.

Logical tests require the presence of a test station on the controller-device interface, which can:

– send DeviceNet messages;
– receive and evaluate DeviceNet messages;
– record and time stamp traffic on the CDI.

9.3.2 Duplicate MAC ID check test

9.3.2.1 Test purpose

The purpose of this test is to verify that the EUT meets the requirements regarding the handling of duplicate MAC ID mechanisms.

9.3.2.2 Test circuit

The test circuit shall be as shown in figure 50.

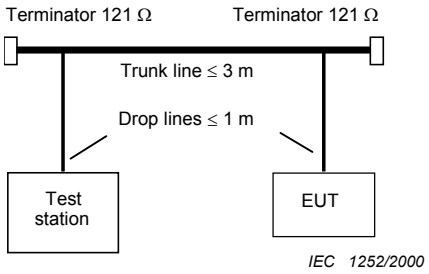


Figure 50 – Test circuit for logical tests

9.3.2.3 Test procedure

9.3.2.3.1 Successful duplicate MAC ID check

The EUT MAC ID shall be set to 0. Any necessary external power shall be applied to the EUT. The EUT shall be physically connected to the link. The test station shall then be connected to the link and shall record the communication traffic.

9.3.2.3.2 Unsuccessful duplicate MAC ID check

The EUT MAC ID shall be set to 0. Any necessary external power shall be applied to the EUT. The EUT shall then be physically connected to the link. The test station shall respond to the first duplicate MAC ID check request message with a duplicate MAC ID check response message.

9.3.2.4 Criteria for compliance

9.3.2.4.1 Successful duplicate MAC ID check

It shall be verified that:

– the EUT transmits a duplicate MAC ID check request message;

– the EUT transmits a second duplicate MAC ID check request between 0,9 s and 1,5 s later;

– the EUT assumes the on-line state no earlier than 0,9 s after transmitting the second duplicate MAC ID check request message;

– the EUT transmits no other messages before assuming the on-line state.

9.3.2.4.2 Unsuccessful duplicate MAC ID check

The EUT shall assume the communication fault state (see table 35) after receiving the duplicate MAC ID check response message.

9.3.3 UCMM

9.3.3.1 Test purpose

The purpose of this test is to determine whether a node that supports the UCMM meets the requirements associated with the creation of explicit messaging connections.

9.3.3.2 Test circuit

The test circuit shall be as shown in figure 50.

9.3.3.3 Test procedure

The test station shall transmit a UCMM open request message using message group 1. After opening this messaging connection, an explicit message shall be transmitted across this connection. The test station shall transmit a UCMM close request message. The test station shall transmit a second explicit message and wait 10 s for a response.

The above procedure shall be repeated for message groups 2 and 3.

9.3.3.4 Criteria for compliance

It shall be verified that:

– the first explicit message is transmitted and received successfully in at least one message group;
– the EUT does not transmit a response to the second explicit message.

9.3.4 Allocation of a predefined master/slave connection set for an explicit messaging connection

9.3.4.1 Test purpose

The purpose of this test is to determine whether the EUT meets the requirements associated with the allocation of a predefined master/slave connection set for explicit messaging connections.

9.3.4.2 Test circuit

The test circuit shall be as shown in figure 50.

9.3.4.3 Test procedure

The test station shall send a request to allocate the predefined master/slave connection set (allocation choice = 1). After allocating this messaging connection, an explicit message shall be transmitted across this connection. The test station shall de-allocate the predefined master/slave connection set (release choice = 1). The test station shall transmit a second explicit message and wait 10 s for a response.

9.3.4.4 Criteria for compliance

It shall be verified that:

– the first explicit message is transmitted and received as defined in the predefined master/slave connection set;
– the EUT does not transmit a response to the second explicit message.

9.3.5 Allocation of a predefined master/slave connection set for an I/O messaging connection

9.3.5.1 Test purpose

The purpose of this test is to determine whether the EUT meets the requirements associated with the allocation of a predefined master/slave connection set for I/O messaging connections.

9.3.5.2 Test circuit

The test circuit shall be as shown in figure 50.

9.3.5.3 Test procedure

The test station shall send a request to allocate the predefined master/slave connection set. After allocating this messaging connection, an I/O message shall be transmitted across this connection. The test station shall de-allocate the predefined master/slave connection set. The test station shall transmit a second I/O message and wait 10 s for a response.

This procedure shall be performed for all allocation choices supported, with the exception of all explicit message allocation choices.

9.3.5.4 Criteria for compliance

It shall be verified that:

– the first I/O message is transmitted and received as defined in the predefined master/slave connection set;

– the EUT does not transmit a response to the second I/O message.

Annex A
(normative)

Common services

A.1 DeviceNet service codes and names

Service codes and names are given in table A.1.

Table A.1 – DeviceNet service codes and names

Service code (hex)	Service name
00	Reserved
01	Get_attributes_all
02	Set_attributes_all
03 – 04	Reserved
05	Reset
06	Start
07	Stop
08	Create
09	Delete
0A – 0C	Reserved
0D	Apply_attributes
0E	Get_attribute_single
0F	Reserved
10	Set_attribute_single
11 – 13	Reserved
14	Error response
15	Restore
16	Save
17	No_operation (NOP)
18 – 31	Reserved

A.2 Common service definitions

A.2.1 General

Object classes/instances that utilise these services shall provide a detailed descrip
specific use and parameter formats, and indicate whether or not any of these s
required. All request service data field parameters and all success response
parameters shall be as shown in table A.2, unless otherwise specified.

Table A.2 – Service data and success response data field parameters

Name	Data type	Description of parameter
Object-specific data	Object/class service-specific	Contains class/instance-specific parameters

A.2.2 Get_attributes_all (service code: 01_{hex})

A.2.2.1 General

Get_attributes_all returns the contents of all attributes of an object or class.

A.2.2.2 Service requirements

The following list details the requirements associated with the get_attributes_all service:

– the structure of the information in the service data field of the response shall conform to the get_attributes_all response structure defined by the object or class;

– if the request is successfully serviced, the service data field of the response contains the attribute data. If an error is detected, then an error response is returned.

A.2.2.3 Request service data field parameters

None.

A.2.2.4 Success response service data field parameters

Service data for a get_attributes_all success response is given in table A.3.

Table A.3 – Service data for get_attributes_all success response

Name	Data type	Description of parameter
Attribute data	Object/class attribute-specific	A stream of information containing all of the attributes

A.2.3 Set_attributes_all (service code: 02_{hex})

A.2.3.1 General

Modifies the contents of the attributes of the class or object.

A.2.3.2 Service requirements

The following list details the requirements associated with the set_attributes_all service:

– the structure of the information in the service data field of the request conforms to the definition of the set_attributes_all request for the object or class;

– if the ability to modify an attribute changes based on the state of the object, the object definition shall provide a detailed description of how this service is affected;

– attributes shall be modified only if all attribute-specific value verifications are successful. The first attribute failing verification shall be specified in the additional error code parameter of the error response message;

– if any other error is detected, then an error response is returned;
– if all verification checks are successful, then the attributes are modified and a set_ attributes_all success response is returned.

A.2.3.3 Request service data field parameters

Service data for a set_attributes_all request is given in table A.4.

Table A.4 – Service data for set_attributes_all request

Name	Data type	Description of parameter
Attribute data	Object/class attribute-specific	A stream of information containing all of the attributes

A.2.3.4 Success response service data field parameters

None.

A.2.4 Reset (service code: 05_{hex})

A.2.4.1 General

Invokes the reset service of the specified class/object.

A.2.4.2 Service requirements

The following list details the requirements associated with the reset service:

– if the execution of the reset service request would place the object/device in a state that enables it to respond to the requester, then the response shall not be returned until the service has completed. Otherwise, the object/device shall respond prior to executing the reset service;
– if an error is detected, then an error response shall be returned. Otherwise, a successful reset response shall be returned.

A.2.5 Start (service code: 06_{hex})

A.2.5.1 General

Invokes the start service of the specified class/object.

A.2.5.2 Service requirements

The following list details the requirements associated with the start service:

– if an error is detected, then an error response shall be returned. Otherwise, a successful start response shall be returned.

A.2.6 Stop (service code: 07_{hex})

A.2.6.1 General

Invokes the stop service of the specified class/object.

A.2.6.2 Service requirements

The following list details the requirements associated with the stop service:

– if an error is detected, then an error response shall be returned. Otherwise, a successful stop response shall be returned.

A.2.7 Create (service code: 08_{hex})

A.2.7.1 General

Creates a new object within the specified class.

A.2.7.2 Service requirements

The following list details the requirements associated with the create service:

– the object instance is created and initialized in accordance with the object definition;

– if an error is detected, the object instance shall not be created and an error response shall be returned. Otherwise, a successful create response shall be returned.

A.2.7.3 Success response service data field parameters

Service data for a create success response is given in table A.5.

Table A.5 – Service data for create success response

Name	Data type	Description of parameter
Instance ID	UINT	Integer value assigned to identify the newly created object
Object-specific data	Object/class service-specific	Contains class/instance specific parameters

A.2.8 Delete (service code: 09_{hex})

A.2.8.1 General

Deletes an object instance of the specified class.

A.2.8.2 Service requirements

The following list details the requirements associated with the delete service:

– all resources are released;

– if an error is detected, then an error response shall be returned. Otherwise, a successful delete response shall be returned.

A.2.9 Apply_attributes (service code: $0D_{hex}$)

A.2.9.1 General

Causes pending attribute values to become active.

A.2.9.2 Service requirements

The following list details the requirements associated with the apply_attributes service:

– data for pending attributes shall be verified before it is used;
– if an error is detected, then an error response shall be returned. Otherwise, a successful apply_attributes response shall be returned.

A.2.10 Get_attribute_single (service code: $0E_{hex}$)

A.2.10.1 General

Returns the contents of the specified attribute.

A.2.10.2 Service requirements

The following list details the requirements associated with the get_attribute_single service:

– the service causes the class/object to return the contents of the specified attribute;
– if an error is detected, then an error response shall be returned. Otherwise, a successful get_attribute_single response shall be returned along with the requested attribute data.

A.2.10.3 Request service data field parameters

Service data for a get_attribute_single request is given in table A.6.

Table A.6 – Service data for get_attribute_single request

Name	Data type	Description of parameter
Attribute ID	USINT	Identifies the attribute to be read/returned

A.2.10.4 Success response service data field parameters

Service data for a get_attribute_single success response is given in table A.7.

Table A.7 – Service data for get_attribute_single success response

Name	Data type	Description of parameter
Attribute data	Attribute-specific	Contains the requested attribute data

A.2.11 Set_attribute single (service code: 10_{hex})

A.2.11.1 General

Modifies an attribute value.

A.2.11.2 Service requirements

The following list details the requirements associated with the set_attribute_single service:

– the attribute data is verified prior to the modification taking place;
– if an error is detected, then an error response shall be returned. Otherwise, a successful set_attribute_single response shall be returned.

A.2.11.3 Request service data field parameters

Service data for a set_attribute_single request is given in table A.8.

Table A.8 – Service data for set_attribute_single request

Name	Data type	Description of parameter
Attribute ID	USINT	Identifies the attribute to be read/returned
Attribute data	Attribute-specific	Contains the value to which the specified attribute is to be modified

A.2.12 Error response (service code: 14_{hex})

A.2.12.1 General

This service is used to respond negatively to a previously received explicit request message. This code shall only be present in an explicit response message.

A.2.12.2 Required behaviour

Not applicable.

A.2.12.3 Request service data field parameters

Not applicable.

A.2.12.4 Service data field parameters

Service data for an error response request is given in table A.9.

Table A.9 – Service data for error response request

Name	Data type	Description of parameter
General error code	USINT	Identifies the encountered error. See annex B for a list of general error codes
Additional code	USINT	Contains an object/service-specific value that further describes the error condition. If the responding object has no additional information to specify, then the value 255 shall be placed within this field

A.2.13 Restore (service code: 15_{hex})

A.2.13.1 General

Restores the contents of a class/object's attributes from a storage location accessible by the save service. The attribute data is copied from a storage area to the currently active memory area used by the class/object.

A.2.13.2 Service requirements

The following list details the requirements associated with the restore service:

– the attribute data shall be verified before the copy from the "storage area" to the "actively used" area is performed;

– if the ability to modify an attribute changes based on the state of the object, the object definition shall provide a detailed description of how this service is affected;
– the attributes shall be modified only if all attribute-specific value verifications are successful. If a verification fails, an error response shall be returned. The first attribute failing verification shall be specified in the additional error code parameter of the error response message;
– if any other error is detected, then an error response shall be returned;
– if all verification checks are successful, then the attributes are modified and a restore success response shall be returned.

A.2.14 Save (service code: 16_{hex})

A.2.14.1 General

Copies the contents of a class/object's attributes to a location accessible by the restore service.

A.2.14.2 Service requirements

The following list details the requirements associated with the save service:

– the service shall report success only after the copy has been completed and verified;
– if an error is detected, then an error response shall be returned. Otherwise, a successful save response shall be returned.

A.2.15 No_operation (NOP) (service code: 17_{hex})

A.2.15.1 General

This service causes the receiving object to return a no_operation response. The receiving object shall not perform any other internal action.

A.2.15.2 Required behaviour

If the object to which the request is delivered supports the service, then a success response shall be returned. Otherwise, an error response shall be returned.

A.2.15.3 Request service data field parameters

None.

A.2.15.4 Success response service data field parameters

None.

Annex B
(normative)

DeviceNet error codes

Table B.1 lists the error codes that may be present in the general error code field of an error response message.

Table B.1 – DeviceNet error codes

Error code (hex)	Error name	Description of error
00 – 01		Reserved
02	Resource unavailable	Resources needed for the object to perform the requested service are unavailable
03 – 07		Reserved
08	Service not supported	The requested service was not implemented or was not defined for this object class/instance
09	Invalid attribute value	Invalid attribute data detected
0A		Reserved
0B	Already in requested mode/state	The object is already in the mode/state being requested by the service
0C	Object state conflict	The object is unable to perform the requested service in its current mode/state
0D		Reserved
0E	Attribute not settable	The attribute specified may not be modified
0F	Privilege violation	A permission/privilege check failed
10	Device state conflict	The current mode/state of the node does not allow the execution of the requested service
11	Reply data too large	The data to be transmitted in the response buffer is larger than the allocated response buffer
12		Reserved
13	Not enough data	The service did not supply enough data to perform the specified operation
14	Attribute not supported	The attribute specified in the request is not supported
15	Too much data	The service supplied more data than was expected
16	Object does not exist	The object specified does not exist in the node
17		Reserved
18	No stored attribute data	The attribute data of this object was not saved prior to the requested service
19	Store operation failure	The attempt to save the attribute data of this object was not successful
1A – 1E		Reserved
1F	Manufacturer-specific error	A manufacturer-specific error has been encountered. The additional code field of the error response defines the particular error encountered. This general error code shall only be used when none of the error codes which are either listed in this table or defined within an object class definition accurately reflects the error
20	Invalid parameter	A parameter associated with the request was invalid. This code shall be used when a parameter does not meet the requirements of this specification and/or the requirements defined in an application object-specification
21 – CF		Reserved
D0 – FF		Reserved for object class-specific error codes

Annex C
(normative)

Connection path attribute definition

C.1 General

The path attribute definition defines the specific application object(s) to/from which data is moved. These attributes may optionally contain configuration information for the referenced application object(s).

A connection path attribute is divided into the following segments:

– logical segment;
– symbolic segment;
– data segment.

A segment contains information defining the segment type, the format of the segment type data and the actual segment data.

C.2 Segment type/format

C.2.1 Introduction

The first byte of each segment of a path attribute is the segment type/format byte. This byte determines how the segment is to be interpreted (see figure C.1).

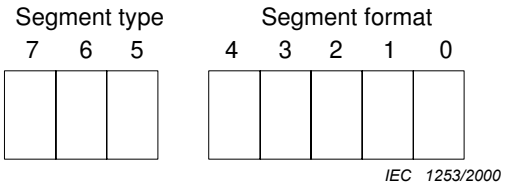


Figure C.1 – Segment type/format

The meaning of the segment format bits is determined by the specified segment type. The segment type bits and associated segment formats are described in the following subclauses.

C.2.2 Logical segment

The logical segment selects a particular application object class, application object instance, and/or application object attribute within a node (see figure C.2).

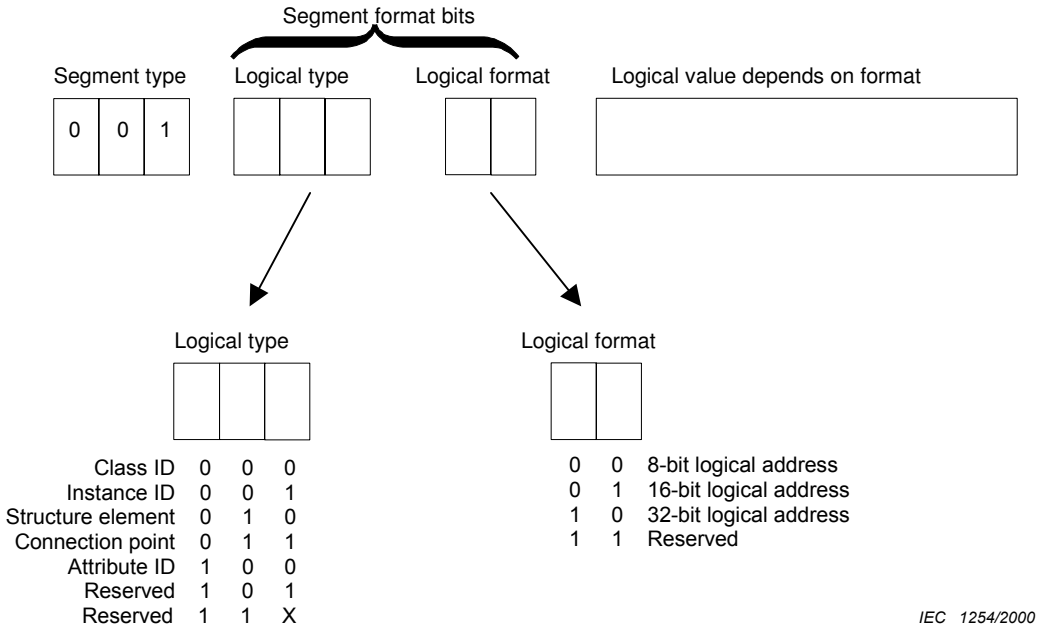


Figure C.2 – Logical segment

C.2.3 Symbolic segment

The symbolic segment contains a string symbol, which shall be interpreted by the device. Symbols may contain a maximum of 31 characters (see figure C.3).

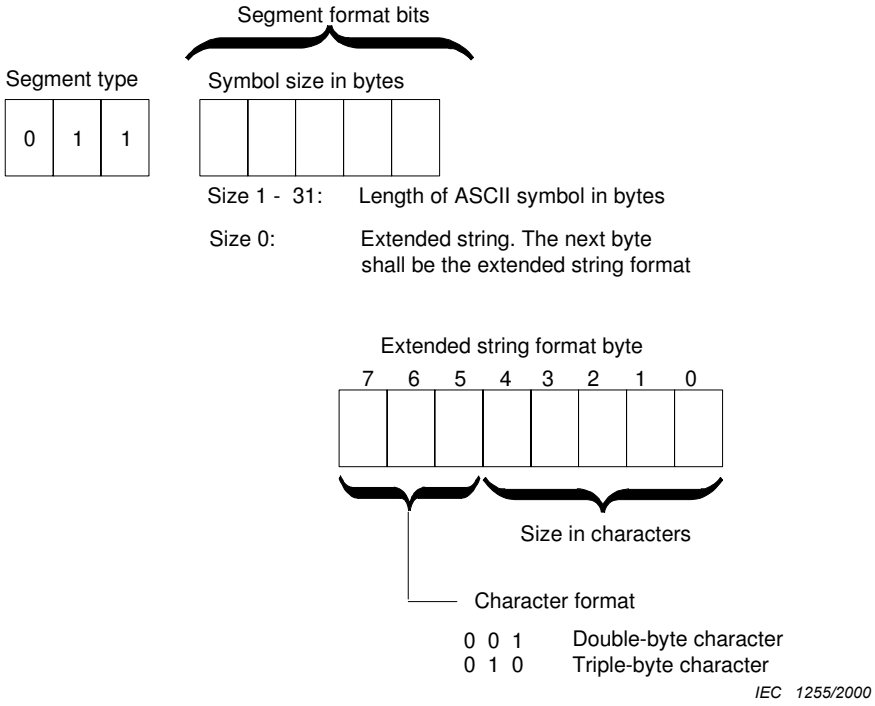


Figure C.3 – Symbolic segment

C.2.4 Data segment

The data segment contains parameters for the target application. The size of the data segment shall be specified in the number of 16 bit words and depends on the application. The data segment may be any number of 16 bit words up to 255. A path may contain more than one data segment, if required (see figure C.4).

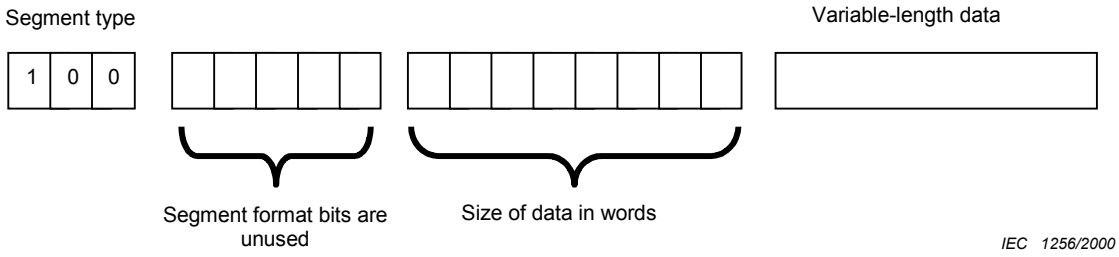


Figure C.4 – Data segment

The data may be configuration information for the object, additional parameters necessary for a connection or any other set of application object-specific information.

C.3 Segment definition rules

The definition of any rules related to the specification of the logical address and any associated data segment information shall be the responsibility of the application object class, i.e. an application object class shall define the means by which it is referenced by a path.

Annex D
(normative)

Data type specification and encoding

D.1 Data type specification

D.1.1 General

The specification of a data type comprises:

– the range of values that variables of the type may assume;
– the operations performed on these variables.

Both elementary and derived data types as defined in IEC 61131-3 are specified. In addition, because the function blocks defined in IEC 61131-3 have both an associated data structure and a set of defined standard operations, these elements are also specified as data types.

D.1.2 Data type value

Data is made up of elementary (primitive) data types. These elementary data types are used to construct derived (constructed) data types.

The elementary data types and the values (range) of variables of each type are given in table D.1, together with the values of certain parameters which are identified as “implementation-dependent” in IEC 61131-3.

Table D.1 – Elementary data types

Keyword	Description	Range	
		Minimum	Maximum
BOOL	Boolean	[1]	
SINT	Short integer	–128	127
INT	Integer	–32768	32767
DINT	Double integer	-2^{31}	$2^{31}-1$
LINT	Long integer	-2^{63}	$2^{63}-1$
USINT	Unsigned short integer	0	255
UINT	Unsigned integer	0	65535
UDINT	Unsigned double integer	0	$2^{32}-1$
ULINT	Unsigned long integer	0	$2^{64}-1$
REAL	Floating point	[2]	
LREAL	Long floating point	[3]	
ITIME	Duration (short)	[12]	
TIME	Duration	[4]	
FTIME	Duration (high resolution)	[5], [6]	
LTIME	Duration (long)	[6], [7]	
DATE	Date only	[8]	
TIME_OF_ DAY or TOD	Time of day	[9]	
DATE_AND_TIME or DT	Date and time of day	[10]	
STRING	Character string (1 byte per character)	[6]	
STRING2	Character string (2 bytes per character)	[6]	
STRINGN	Character string (N bytes per character)	[6]	
SHORT_STRING	Character string (1 byte per character, 1-byte length indicator)	[6]	
BYTE	Bit string – 8 bits	[11]	
WORD	Bit string – 16 bits	[11]	
DWORD	Bit string – 32 bits	[11]	
LWORD	Bit string – 64 bits	[11]	
STRUCT	Structured data types	Not applicable	

[1] The possible values of variables of type BOOL shall be 0 and 1, corresponding to FALSE and TRUE respectively.

[2] The range and encoding of values for variables of type REAL are defined in IEC 61131-3 for the basic single floating point format.

[3] The range and encoding of values for variables of type LREAL are defined in IEC 61131-3 for the basic double floating point format.

[4] The range and encoding of values for variables of type TIME are the same as for variables of type DINT, representing the time duration in milliseconds, i.e. a range of –24d20h31m23,648s to +24d20h31m23,647s.

[5] The range and encoding of values for variables of type FTIME are the same as for variables of type DINT, representing the time duration in microseconds, i.e. a range of –35m47,483648s to +35m47,483547s.

[6] This is an extension to IEC 61131-3.

[7] The range and encoding of values for variables of type LTIME are the same as for variables of type LINT, representing the time duration in microseconds, i.e. a range of –106751991d4h0m54,775808s to +106751991d4h0m54,775807s.

[8] The encoding of values for variables of type DATE is the same as for variables of type UINT, representing the range from 1972-01-01, the start of the Coordinated Universal Time (UTC) era, to 2151-06-06 (a total range of 65536 days).

[9] The encoding of values for variables of type TIME_OF_DAY is the same as for values of type UDINT, representing the range from TOD = 00:00:00,000 to TOD = 23:59:59,999 with a resolution of 1 ms.

[10] The range of values for variables of type DATE_AND_TIME is from 1972-01-01-00:00:00,000 to 2151-06-06-23:59:59,999.

[11] The values of bit string data types are in the range bN–1 to b0, where N is the number of bits.

[12] The range and encoding of values for variables of type ITIME are the same as for variables of type INT, representing the time duration in milliseconds, i.e. a range of –32s768 ms to +32s767 ms.

D.1.3 Language extensions

The following language extensions to IEC 61131-3 are allowed:

– ITIME data type
  FTIME data type
  LTIME data type
  STRING2 data type
  STRINGN data type
  SHORT_STRING data type;
– structured bit string types;
– operations on STRING2 variables;
– numbered bit string access;
– structured bit string access.

D.2 Data type encoding

D.2.1 General

Values shall be encoded with the least significant byte first. The least significant bit of each byte shall also be encoded first. The encoding for each data type is described below.

D.2.2 Boolean

A Boolean value shall be encoded in a single byte, with the value 0 for FALSE and 1 for TRUE.

D.2.3 SINT, USINT and BYTE

These 8-bit values shall be encoded in a single byte.

D.2.4 INT, UINT and WOR

These 16-bit values shall be encoded in two bytes, the least significant byte first.

D.2.5 REAL, DINT, UDINT and DWORD

These 32-bit values shall be encoded in four bytes, the least significant byte first. The assignment of a REAL value uses the IEC 61131-3 notation.

D.2.6 LREAL, LINT, ULINT and LWORD

These 64-bit values shall be encoded in eight bytes, the least significant byte first. The assignment of an LREAL value uses the IEC 61131-3 notation.

D.2.7 STRING

This value shall be encoded as a 16-bit character count value, the least significant byte first, followed by one-byte characters.

D.2.8 STRING2

This value shall be encoded as a 16-bit character count value, the least significant byte first, followed by two-byte characters. The two-byte characters are encoded with the least significant byte first.

D.2.9 STRINGN

This value shall be encoded as a 16-bit character size value (*n*), the least significant byte first, followed by a 16-bit character count value, the least significant byte first, followed by *n*-byte characters. The *n*-byte characters are encoded with the least significant byte first.

D.2.10 SHORT_STRING

This value shall be encoded as an 8-bit character count value, followed by one-byte characters.

D.2.11 DATE_AND_TIME

This value shall be encoded as TIME_OF_DAY followed by DATE.

D.2.12 STRUCT

This value is a group of data types.

Annex E
(normative)

Communication objects library

E.1 General

DeviceNet communication in a node is modelled as a collection of objects. An object provides an abstract representation of a data structure within a node.

An object class is a set of objects that all represent the same type of object. An object instance is the actual representation of a particular object within a class. Each instance of a class has the same set of attributes, but has its own particular set of attribute values.

An object instance and/or an object class have attributes, provide services and implement a behaviour.

Attributes are the characteristics of an object and/or an object class. Attributes provide status information or govern the operation of an object. Services are invoked to trigger the object class or instance to perform a task. The behaviour of an object indicates how it responds to particular events.

E.2 Object class codes

Table E.1 lists object class codes and their names.

Table E.1 – Object class codes and names

Code	Name
01_{hex}	Identity
02_{hex}	Message router
03_{hex}	DeviceNet
05_{hex}	DeviceNet connection
$2B_{hex}$	Acknowledgement handler
NOTE All other public class codes are reserved.	

E.3 Identity object (class code: 01_{hex})

E.3.1 General

The identity object identifies and provides general information about the node. The identity object shall be present in all DeviceNet nodes.

If autonomous components of a node exist, multiple instances of the identity object shall be used.

E.3.2 Class attributes

The identity object instance attributes are described in table E.2.

Table E.2 – Identity object class attributes

Attribute ID	Need in implemen-tation	Access rule	Name	DeviceNet data type	Description of attribute	Value
1	Optional	Get	Revision	UINT	Revision of this object	The value assigned to this attribute shall be one (1)
2	Optional	Get	Maximum instance	UINT	Maximum instance number of an object currently created in this class level of the node	The largest instance number of a created object at this class hierarchy level
NOTE All other public attribute IDs are reserved.						

E.3.3 Instance attributes

The identity object instance attributes are described in table E.3.

Table E.3 – Identity object instance attributes

Attribute ID	Need in implemen-tation	Access rule	Name	DeviceNet data type	Description of attribute
1	Required	Get	Manufac-turer	UINT	Identification of each manufacturer by number
2	Required	Get	Device type	UINT	Indication of general type of product
3	Required	Get	Product code	UINT	Identification of a particular product of an individual manufacturer
4	Required	Get	Revision	STRUCT	Revision of the item the identity object represents
			Major revision	USINT	
			Minor revision	USINT	
5	Required	Get	Status	WORD	Summary status of device
6	Required	Get	Serial number	UDINT	Serial number of device
7	Required	Get	Product name	SHORT_ STRING	Human readable identification
8	Optional	Get	State	USINT	Present state of the device
NOTE All other public attribute IDs are reserved.					

The following terms are used in the names of the identity object instance attributes:

manufacturer: unique value allocated to each manufacturer;

device type: a device type is used to identify similar devices which:

- exhibit the same behaviour;
- produce and/or consume the same set of data;
- contain the same set of configurable attributes.

Additionally, the device type will also provide a scope for the product code numbers.

See annex F for definition of allowed device type values.

product code: the product code identifies a product within a particular device type. Each manufacturer shall assign a product code to each of his products. The value zero is invalid and shall not be used;

revision: the revision attribute, which consists of major and minor revisions, identifies the revision of the item that the identity object is representing. The major revision attribute is limited to 7 bits – the eighth bit shall be set to zero. The value zero is not valid for either field;

status: this attribute represents the current status of the entire node. Its value changes as the state of the node changes. The status attribute is a word, with the bit definitions as given in table E.4;

Table E.4 – Bit definitions for status instance attribute of identity object

Bit (s)	Called	Definition
0	Owned	TRUE indicates that the node (or an object within the node) has an owner. For master/slave communications, the setting of this bit means that the predefined master/slave connection set has been allocated to a master. For non-master/slave communications, the meaning of this bit is not defined
1		Shall be set to 0
2	Configured	TRUE indicates that the application of the node has been configured to do something different to the initial default. This does not include configuration of the communications
3		Shall be set to 0
4,5,6,7		Manufacturer-specific
8	Minor recoverable fault	TRUE indicates that the node detected a recoverable problem with itself. The problem does not cause the node to go into one of the faulted states. See E.3.6
9	Minor unrecoverable fault	TRUE indicates that the node detected an unrecoverable problem with itself. The problem does not cause the node to go into one of the faulted states. See E.3.6
10	Major recoverable fault	TRUE indicates that the node detected a problem with itself which caused the node to go into the “major recoverable fault” state. See E.3.6
11	Major unrecoverable fault	TRUE indicates that the node detected a problem with itself which caused the node to go into the “major non-recoverable fault” state. See E.3.6
12, 13 ,14, 15		Shall be set to 0

The events that constitute a fault (recoverable or unrecoverable) shall be determined by the manufacturer.

serial number: see 3.42;

product name: 32-character string (maximum) defined by the manufacturer;

state: the state of the node shall be represented as follows:

0 = Non-existent
1 = Device self-testing
2 = Standby
3 = Operational
4 = Major recoverable fault
5 = Major unrecoverable fault
6 – 254 = Reserved
255 = Default value if attribute is not supported

E.3.4 Common services

E.3.4.1 General

The identity object shall provide the common services listed in table E.5.

Table E.5 – Identity object common services

Service code	Need in implementation		Service name	Description of service
	Class	Instance		
$0E_{hex}$	Optional[1)]	Required	Get_attribute_single	Returns the contents of the specified attribute
05_{hex}	Optional	Required	Reset	Invokes the reset service for the device
01_{hex}	Optional	Optional	Get_attributes_all	Returns a predefined listing of this object's attributes (see E.3.4.3)
[1)] The get_attribute_single service is required if any attribute is implemented.				

E.3.4.2 Reset service

When the identity object receives a reset request, it shall:

– determine if it is able to provide the type of reset requested;
– respond to the request;
– attempt to perform the type of reset requested.

The reset service has the object-specific parameter given in table E.6.

Table E.6 – Identity object reset request

Name	Type	Description of request parameters
Type	USINT	Type of reset

The parameter type for the reset service has the bit specifications given in table E.7.

Table E.7 – Identity reset service parameter values

Value	Type of reset
0	Emulate as closely as possible cycling power on the item the identity object represents. This value is the default value if this parameter is omitted
1	Return as closely as possible to the initial configuration, then emulate cycling power as closely as possible

E.3.4.3 Get_attributes_all response

At the class level, the order of the attributes returned in the “object/service-specific reply data” portion of the get_attributes_all response shall be as given in table E.8.

Table E.8 – Identity object get_attributes_all response, class level

Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	Revision (low byte); default = 1							
1	Revision (high byte); default = 0							
2	Max. instance (low byte); default = 1							
3	Max. instance (high byte); default = 0							
NOTE Default values shall be used for all unsupported attributes.								

At the instance level, the order of the attributes returned in the “object/service-specific reply data” portion of the get_attributes_all response shall be as given in table E.9:

Table E.9 – Identity object get_attributes_all response, instance level

Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	Manufacturer (low byte)							
1	Manufacturer (high byte)							
2	Device type (low byte)							
3	Device type (high byte)							
4	Product code (low byte)							
5	Product code (high byte)							
6	Major revision							
7	Minor revision							
8	Status (low byte)							
9	Status (high byte)							
10	Serial number (low byte)							
11	Serial number							
12	Serial number							
13	Serial number (high byte)							
14	Product name length							
15	Product name (1st character)							
16	Product name (2nd character)							
n	Product name (last character)							
n+1	State default value = 255							
NOTE Default values shall be inserted for all unsupported attributes.								

E.3.5 Object-specific services

The identity object provides no object-specific services.

E.3.6 Behaviour

The behaviour of the identity object is shown in the state transition diagram in figure E.1. This state transition diagram associates the state of the device with the status reported by the status attribute and the state of the module status indicator.

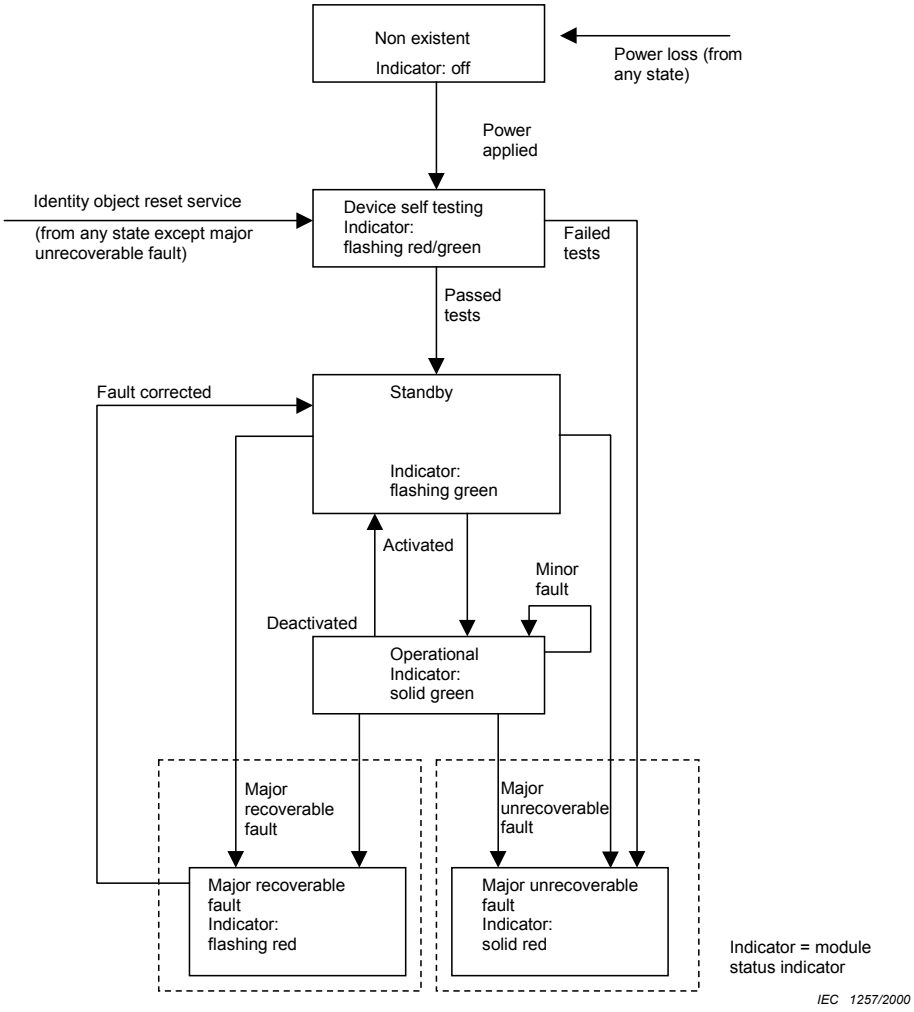


Figure E.1 – State transition diagram for identity object

The state transition diagram for the identity object contains the following events:

– **power applied:** the device has power applied;

– **power loss:** the device is no longer powered;

– **passed tests:** the node has successfully passed all self-tests;

– **activated:** the device's configuration is valid and the application for which the device was designed is now capable of executing (communications channels may or may not yet be established);

– **deactivated:** the device's configuration is no longer valid and the application for which the device was designed is no longer capable of executing (communication channels may or may not still be established);

– **minor fault:** an event classified as either a minor unrecoverable fault or a minor recoverable fault has occurred;

– **major recoverable fault:** an event classified as major recoverable fault has occurred;

– **major unrecoverable fault:** an event classified as a major unrecoverable fault has occurred;

– **fault corrected:** major recoverable fault corrected or cleared;

– **failed test(s):** major unrecoverable fault;

– **reset service:** see E.3.4.2.

The state-event matrix for the identity object (see table E.10) contains the following states:

– **non-existent**: power is not applied to the device;
– **device self-testing:** the device is executing its self-tests;
– **standby:** the device needs commissioning due to an incorrect or incomplete configuration;
– **operational:** the device is operating in a fashion that is normal for the device;
– **major recoverable fault:** the device has experienced a recoverable fault;
– **major unrecoverable fault:** the device has experienced an unrecoverable fault.

Table E.10 – State-event matrix for identity object

Event	Non-existent	Device self-testing	Standby	Operational	Major unrecoverable fault	Major recoverable fault
Power loss	Not applicable	Transition to non-existent	Transition to non-existent	Transition to non-existent	Transition to non-existent	Transition to non-existent
Power applied	Transition to device self-testing	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Failed tests	Not applicable	Transition to major unrecoverable fault	Not applicable	Not applicable	Not applicable	Not applicable
Passed tests	Not applicable	Transition to standby	Not applicable	Not applicable	Not applicable	Not applicable
Deactivated	Not applicable	Ignore event	Ignore event	Transition to standby	Ignore event	Ignore event
Activated	Not applicable	Ignore event	Transition to operational	Ignore event	Ignore event	Ignore event
Major recoverable fault	Not applicable	Not applicable	Transition to major recoverable fault	Transition to major recoverable fault	Ignore event	Ignore event
Major unrecoverable fault	Not applicable	Not applicable	Transition to major unrecoverable fault	Transition to major unrecoverable fault	Ignore event	Ignore event
Minor fault	Not applicable	Ignore event	Ignore event	Ignore event	Ignore event	Ignore event
Fault corrected	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Transition to standby
Reset	Not applicable	Restart self-tests	Transition to device self-testing	Transition to device self-testing	Ignore event	Transition to device self-testing

E.4 Message router object (class code: 02_{hex})

E.4.1 General

The message router object provides a messaging connection point through which a client may address a service to any object class or instance residing in the node.

E.4.2 Class attributes

The message router class attributes are described in table E.11.

Table E.11 – Message router class attributes

Attribute ID	Need in implementation	Access rule	Name	DeviceNet data type	Description of attribute	Meaning of values
1	Optional	Get	Revision	UINT	Revision of this object	The value assigned to this attribute is one (1)
NOTE All other public attribute IDs are reserved.						

E.4.3 Instance attributes

The message router instance attributes are described in table E.12.

Table E.12 – Message router instance attributes

Attribute ID	Need in implementation	Access rule	Name	DeviceNet data type	Description of attribute	Meaning of values
1	Optional	Get	Object_ list	STRUCT	List of supported objects	Structure with an array of class codes supported by the device
			Number	UINT	Number of members in the class array	Number of class codes in the class array
			Classes	Array of UINT	List of supported class codes	Class codes supported by the device
2	Optional	Get	Number available	UINT	Maximum number of connections supported	Count of the maximum number of connections supported
3	Optional	Get	Number active	UINT	Number of connections currently used by system components	Current count of the number of connections allocated to system communication
4	Optional	Get	Active connec-tions	Array of UINT	List of the connection IDs of the currently active connections	Array of system connection IDs
NOTE All other public attribute IDs are reserved.						

E.4.4 Common services

E.4.4.1 General

The message router object shall provide the following common services (see table E.13).

Table E.13 – Message router common services

Service code	Need in implementation		Service name	Description of service
	Class	Instance		
$0E_{hex}$	Optional[1)]	Optional[1)]	Get_attribute_single	Returns the contents of the specified attribute
01_{hex}	Optional	Optional	Get_attributes_all	Returns the contents of all attributes
[1)] The get_attribute_single service is required if any attribute is implemented.				

E.4.4.2 Get_attributes_all response

At the class level, the order of the attributes returned in the “object/service-specific reply data” portion of the get_attributes_all response shall be as given in table E.14.

Table E.14 – Get_attributes_all response, class level

Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	Revision (low byte); default = 1							
1	Revision (high byte); default = 0							
NOTE Default values shall be used for all unsupported attributes.								

At the instance level, the order of the attributes returned in the “object/service-specific reply data” portion of the get_attributes_all response shall be as given in table E.15.

Table E.15 – Get_attributes_all response, instance level

Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	Object_list : number (low byte); default = 0							
1	Object_list : number (high byte); default = 0							
2	Object_list : class no. 1 (low byte)							
3	Object_list : class no. 1 (high byte)							
2n	Object_list : class no. n (low byte)							
2n+1	Object_list : class no. n (high byte)							
2n+2	Number available (low byte); default = 0							
2n+3	Number available (high byte); default = 0							
2n+4	Number active (low byte); default = 0							
2n+5	Number active (high byte); default = 0							
2n+6	Active connections no. 1 (low byte)							
2n+7	Active connections no. 1 (high byte)							
2n+2m+4	Active connections no. m (low byte)							
2n+2m+5	Active connections no. m (high byte)							
NOTE 1 Default values shall be used for all unsupported attributes. NOTE 2 If the instance attribute object_list is not supported, the default value of zero shall be inserted into the response byte array without any object_list class numbers. NOTE 3 If the Instance attribute “number active” is not supported, the default value of zero shall be inserted into the response byte array without any active connection numbers.								

E.4.5 Object-specific services

The message router object provides no object-specific services.

E.4.6 Behaviour

E.4.6.1 General

The message router object shall receive explicit messages and perform the following functions:

– interpret the class instance specified in a message;

– route a service to the specified object;

– interpret services directed to it;

– route a response to the correct service source.

E.4.6.2 Service request

Interpretation of the class instance shall be performed on every service received by the message router. Any class instance that cannot be interpreted by a node's implementation of a message router shall report the object_not_found error. If no error is detected, the service shall then be routed to a target object.

E.4.6.3 Service response

All service responses shall be routed to the explicit messaging connection across which the service request was received.

E.5 DeviceNet object (class code: 03_{hex})

The DeviceNet object (see 5.3.3) provides the configuration and status of a DeviceNet port. Each DeviceNet device shall support only one DeviceNet object per physical connection to the DeviceNet communication link.

E.6 DeviceNet connection object (class code: 05_{hex})

The DeviceNet connection object manages the characteristics of a communication connection (see 5.3.2).

E.7 Acknowledgement handler object (class code: $2B_{hex}$)

E.7.1 General

The acknowledgement handler object manages the reception of message acknowledgements. This object communicates with a message-producing application object within a device. The acknowledgement handler object notifies the producing application of the acknowledgement reception, acknowledgement time-outs, and production retry limit.

E.7.2 Class attributes

The acknowledgement handler object class attributes are described in table E.16.

Table E.16 – Acknowledgement handler object class attributes

Attribute ID	Need in implemen-tation	Access rule	Name	DeviceNet data type	Description of attribute	Value
1	Optional	Get	Revision	UINT	Revision of this object	The value assigned to this attribute shall be one (1)
2	Optional	Get	Maximum instance	UINT	Maximum instance number of an object currently created in this class level of the node	Largest instance number of a created object at this class hierarchy level
NOTE All other public attribute IDs are reserved.						

E.7.3 Instance attributes

The acknowledgement handler object instance attributes are described in table E.17.

Table E.17 – Acknowledgement handler instance attributes

Attribute ID	Need in implemen-tation	Access rule	Name	DeviceNet data type	Description of attribute	Value
1	Required	Set	Acknow-ledgement timer	UINT	Time to wait for acknowledgement before resending	Range 1-65535 ms (0 invalid); default = 16
2	Required (Get) Optional (Set)	Get/Set	Retry limit	USINT	Number of ack time-outs to wait before informing the producing application of a retrylimit_reached event	Range 0-255; default = 1
3	Required	Get/Set (inactive) Get (active)	COS producing connection instance	UINT	Connection instance which contains the path of the producing I/O application object which shall be notified of ack handler events	Connection instance ID
4	Optional	Get	Ack list size	BYTE	Maximum number of members in ack list	0 = Dynamic >0 = Maximum number of members
5	Optional	Get	Ack list	BYTE Array of UINT	List of active connection instances which are receiving acks	Number of members followed by list of connection instance IDs
6	Optional	Get	Data with ack path list size	BYTE	Maximum number of members in data with ack path list	0 = Dynamic >0 = Maximum number of members
7	Optional	Get	Data with ack path list	BYTE Array of: – UINT – USINT – Array of USINT	List of connection instance/consuming application object pairs. This attribute shall be used to forward data received with acknowledgement	Number of members followed by list of connection instance ID/DeviceNet path length/DeviceNet path

NOTE 1 If the specified value for the acknowledgement timer attribute is not equal to an increment of the available clock resolution, then the value shall be rounded up to the next serviceable value.

NOTE 2 The value that shall be loaded into the acknowledgement timer attribute shall be reported in the service data field of a set_attribute_single response message associated with a request to modify this attribute.

NOTE 3 A successful set_attribute request to the retry limit attribute shall reset the retry counter.

NOTE 4 The ack list attribute shall be updated when an associated connection transitions between configuring, established, timed-out, and non-existent. Refer to the state-event matrix for details.

NOTE 5 If the acknowledgement handler object is active (at least one member in the ack list), the COS producing connection instance attribute access shall be "Get" only.

NOTE 6 The default value loaded into the acknowledgement timer attribute at the time of instantiation shall be 16 ms.

NOTE 7 The default value loaded into the retry limit attribute at the time of instantiation shall be 1.

NOTE 8 All other public attribute IDs are reserved.

E.7.4 Common services

The acknowledgement handler object shall provide the common services given in table E.18.

Table E.18 – Acknowledgement handler object common services

Service code	Need in implementation		Service name	Description of service
	Class	Instance		
$0E_{hex}$	Optional	Required	Get_attribute_single	Returns the contents of the specified attribute
10_{hex}	Not applicable	Required	Set_attribute_single	Modifies an attribute value
08_{hex}	Optional	Not applicable	Create	Creates an acknowledgement handler object
09_{hex}	Optional	Optional	Delete	Deletes an acknowledgement handler object
NOTE If the delete service is addressed to the class, all instances shall be deleted. If it is addressed to a specific instance, only this one shall be deleted.				

E.7.5 Object-specific services

The acknowledgement handler object shall provide the object-specific services given in table E.19.

Table E.19 – Acknowledgement handler object-specific services

Service code	Need in implementation		Service name	Description of service
	Class	Instance		
$4B_{hex}$	Not applicable	Optional	Add_ackdata_path	Adds a path for data returned with acknowledgement for a connected consumer
$4C_{hex}$	Not applicable	Optional	Remove_ackdata_path	Removes a path for data returned with acknowledgement for the given connected consumer

These services are used to add and remove paths for each of the connected acknowledgement consumers when data is sent with the acknowledgement. See table E.20 and table E.21.

Table E.20 – Acknowledgement handler add_ackdata_path request

Name	Type	Description of request parameters
Connection instance ID	UINT	Integer value assigned to identify the producer connection
DeviceNet path length	UINT	Number of bytes in the DeviceNet path attribute
DeviceNet path	Array of USINT	Specifies the application object(s) which shall receive the data sent with the acknowledgement

Table E.21 – Acknowledgement handler remove_ackdata_path request

Name	Type	Description of request parameters
Connection instance ID	UINT	Integer value assigned to identify the producer connection

E.7.6 Behaviour and configuration of acknowledged data production

E.7.6.1 General

The following rules shall be used to configure and determine the behaviour of an acknowledged change of state or cyclic I/O connection using the acknowledgement handler object. In the following examples, the term COS producer is used to reference the device producing the change of state or cyclic data and consuming an acknowledgement (client). The term COS consumer is used to reference the device consuming the change of state or cyclic data and producing an acknowledgement (server).

E.7.6.2 Acknowledged data production

The following rules shall be used:

– the COS producer's consumed_connection_path attribute shall be set to an available acknowledgement handler object. The path shall consist of a class and an instance. If an acknowledgement handler object is not available, then the acknowledgement handler class create service shall be used to obtain a new one;

– the COS producer's producing I/O application shall inform the acknowledgement handler object of new data production (data sent event message) or data production retries (data resent event message);

– the COS producer's acknowledgement reception shall be performed by the acknowledgement handler object. The acknowledgement handler object informs the producing I/O application when one or more acknowledgements have not been received within the acknowledgement time-out (using the ack list and acknowledgement timer attributes);

– the acknowledgement message requires no data. The COS producing device's acknowledgement handler object shall consider a valid message reception as an acknowledgement. However, a change of state or cyclic producing device may be configured to consume data along with the acknowledgement. In this case, the data shall be forwarded to the application object in the "data with ack path list" attribute, based on the connection which received the data;

– the COS consumer acknowledgement producing application shall be configured to send either a zero length message or a valid response (output) message when a valid input message may be consumed;

– an acknowledgement timer shall be started each time a production occurs. The acknowledgement handler object shall be notified of this event by a data sent or data resent event message from the producing application;

– expiry of the acknowledgement timer shall cause an acknowledgement time-out message to be sent to the producing application object. This object shall resend the last message if the retry limit has not been reached. It may also take an application-specific action;

– the retry count shall be incremented each time an acknowledgement time-out message is sent to the producing application. When the retry limit has been reached, a retry limit reached message shall be sent to the producing application object;
– the retry count shall be cleared on each data sent message. A data resent message shall not clear the retry counter;
– the acknowledgement timer value shall be configurable within the acknowledgement handler object;
– the number of retries may be configurable within the acknowledgement handler object.

E.7.6.3 Acknowledged change of state (using one connection object and one COS consumer)

The producer shall either perform or be aware of the following steps:

– the producer shall create a connection object;
– the producer transportclass_trigger attribute shall be set to class 2/3, change of state, client (13_{hex} for class 3) or class 2/3, cyclic, client (03_{hex} for class 3);
– the produced_connection_path attribute shall be set to the producing application, which shall support change of state or cyclic production;
– the producer shall create an acknowledgement handler object and configure the “COS producing connection instance” attribute to the instance of the connection object which specifies the producing I/O application object. The ack list attribute shall be updated with the connection instance of the I/O connection object which shall consume an acknowledgement, as that connection transitions to the established state. Optionally, the producer may configure the acknowledgement timer and retry count attributes;
– the consumed_connection_path attribute shall be set to the acknowledgement handler object created and configured for handling the acknowledgement. This path contains class and instance only;
– the consumed_connection_size attribute shall be set to the size of the data expected to be delivered to the object specified in the consumed path of the acknowledgement handler object, or zero if no path is configured;
– the producer shall configure all other attributes in the same way as any other peer to peer connection.

The consumer shall either perform or be aware of the following steps:

– the consumer transportclass_trigger attribute is set to class 2/3, server (83_{hex} for class 3);
– the produced_connection_path attribute shall be set to the consuming application (or some other application as this is product-specific) for generating the acknowledgement;
– the produced_connection_size attribute shall be set to the size of the data to be delivered to the object specified in the consumed path of the change of state producing device’s acknowledgement handler object, or zero if no path is configured;
– the consumer shall configure all other attributes in the same way as any other peer to peer connection.

E.7.6.4 Acknowledged change of state (using multiple connection objects and COS consumers)

The producer shall either perform or be aware of the following steps:

– the producer shall create a connection object;

– the producer transportclass_trigger attribute shall be set to class 0, change of state, client (10_{hex}) or class 0, cyclic, client (00_{hex});

– the produced_connection_path attribute shall be set to the producing application, which shall support change of state, or cyclic production;

– the consumed_connection_path and consumed_connection_size attributes shall not be configured by the producer;

– the producer shall configure all other attributes in the same way as any other peer to peer connection;

– the producer shall create a connection object for each COS consumer;

– the consumer transportclass_trigger attribute shall be set to class 0, server (80_{hex}) for each consuming connection object;

– the producer shall create an acknowledgement handler object and configure the “COS producing connection instance” attribute to the instance of the connection object which specifies the producing I/O application object. The ack list attribute shall be updated with the connection instance of each I/O connection object which shall consume an acknowledgement, as those connections transition to the established state. Optionally, the producer may configure the acknowledge timer and retry count attributes;

– the consumed_connection_path attribute for each consuming connection object shall be set to the acknowledgement handler object just created and configured for handling the acknowledge. The path contains class and instance only;

– the consumed_connection_size attribute shall be set to the size of the data expected to be delivered to the consumed path set in the acknowledgement handler object, or zero if no path is configured;

– the producer shall configure all other attributes in the same way as any other peer to peer connection.

Each consumer shall either perform or be aware of the following steps:

– the consumer transportclass_trigger attribute shall be set to class 2/3, server (83_{hex} for class 3);

– the produced_connection_path attribute shall be set to the consuming application (or some other application as this is product-specific) for generating the acknowledgement;

– the produced_connection_size attribute shall be set to the size of the data to be delivered to the consumed path set in the change of state producing device’s acknowledgement handler object, or zero if no path is configured;

– the consumer shall configure all other attributes in the same way as any other peer to peer connection.

Once the connection object(s) are configured, an apply_attributes service shall be sent to each configured connection object to transition the connection(s) to the established state. During the apply_attributes, the connection object shall be "delivered" to both the consuming and producing application objects for validation of the attribute information. At this time, the producing I/O application shall check for a change of state configuration by examining the transportclass_trigger attribute. If the production trigger bits are set to change of state or cyclic, the application shall configure itself for change of state or cyclic production. If the change of state or cyclic production is not supported by the producing application object, an error shall be returned to the apply_attributes service.

E.7.6.5 Use of timers with acknowledged data production

The following rules shall be observed when sending acknowledged data:

– new data shall not be sent while the inhibit timer is active (running);

– new data shall be sent when no acknowledgement is pending, subject to the above rule. An acknowledgement shall be pending after a send of new data or a retry of old data, and until an ack time-out or ack received;

– retrying old data shall occur at ack time-out if new data is not available or the inhibit timer is active;

– sending new data (or old data on transmission trigger timeout) shall start the ack timer, inhibit timer and the transmission trigger timer. The retry counter shall be also cleared;

– retrying old data shall start the ack timer.

E.7.6.6 Timing

Figure E.2 shows typical timing relationships for acknowledged data production.

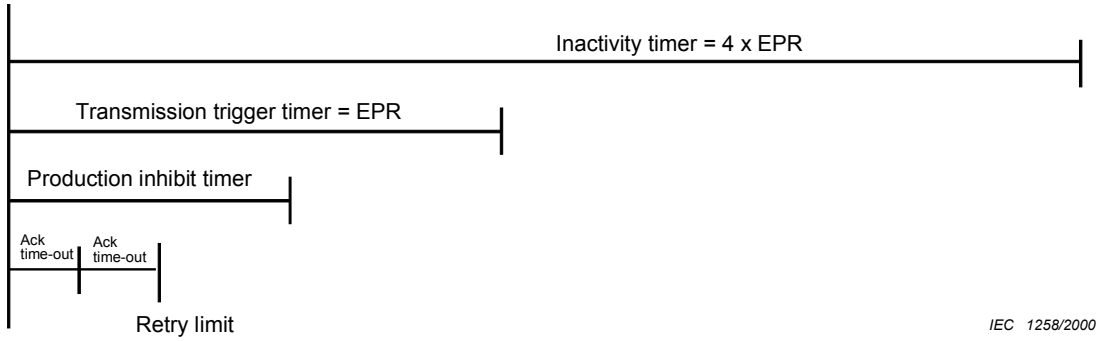


Figure E.2 – Typical timing relationships for acknowledged data production

Figure E.3 shows a typical timing diagram for a change of state system.

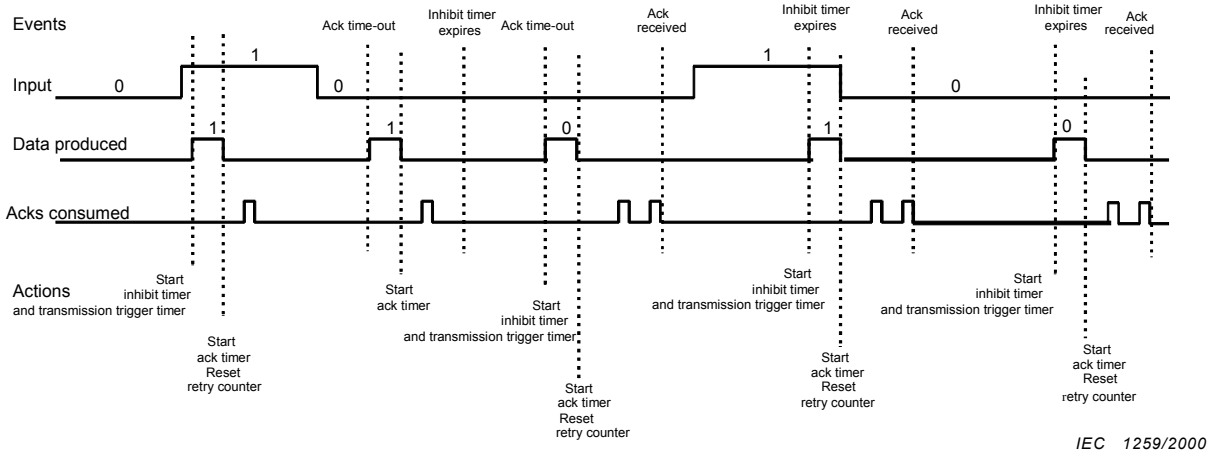


Figure E.3 – Typical timing diagram for a change of state system

E.7.6.7 Message flow

Figure E.4 and figure E.5 illustrate the message flow in a change of state connection for both single and multi-consumer configurations.

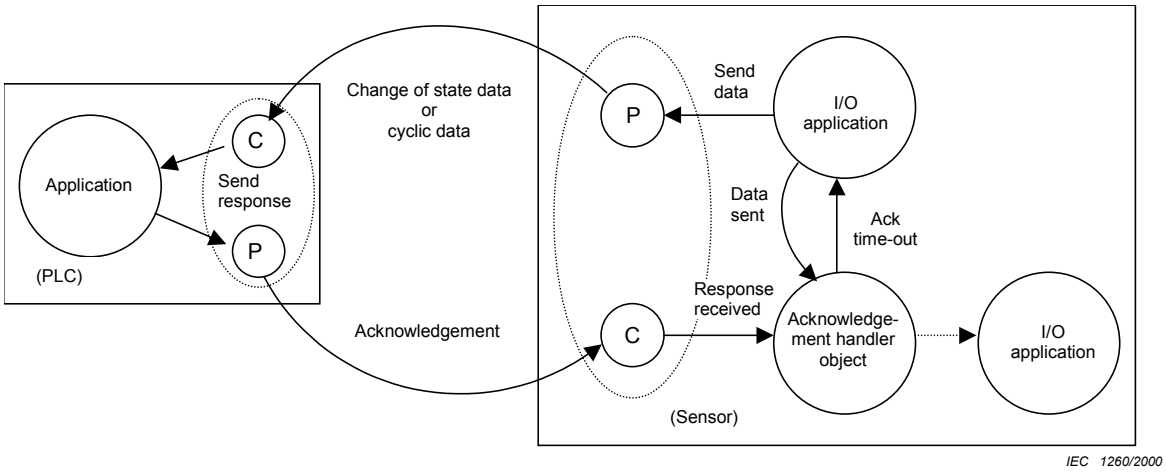


Figure E.4 – Message flow – One connection object, one consumer

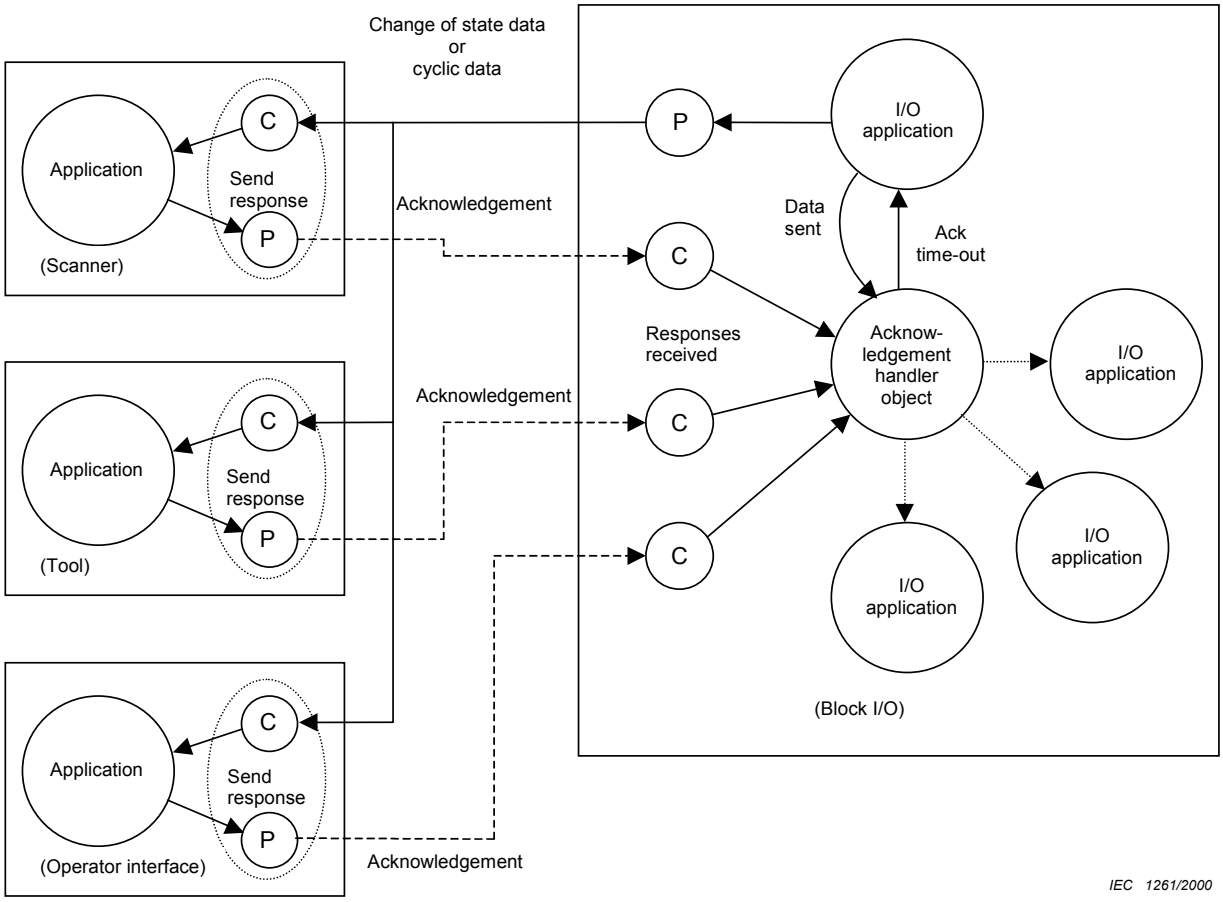


Figure E.5 – Message flow – Multi-consumer configuration

E.7.6.8 State-event matrices

Table E.22 and table E.23 are the state-event matrices for the producing I/O application object and acknowledgement handler object associated with a change of state connection.

Table E.22 – State-event matrix for producing I/O application object

Event	State			
	Not running	Running	Running with acknowledgement	Prohibited
Change of state detected	Ignore event	Inform link producer to send data If inhibit time configured: – start inhibit timer – transition to prohibited	Inform link producer to send data Send data_sent event message to acknowledgement handler object If inhibit time configured: – start inhibit timer – transition to prohibited	Queue event
Acknowledge_ received	Not applicable	Not applicable	Ignore event	If ack_active set: if inhibit timer not running, transition to running with acknowledgement else set ack_received flag Else ignore event
Acknowledge_timeout	Ignore event	Not applicable	Inform link producer to send data Send data_resent event message to acknowledgement handler object	Inform link producer to send data Send data_resent event message to acknowledgement handler object
Transmission timer expires	Not applicable	Inform link producer to send data	Inform link producer to send data Send data_sent event message to acknowledgement handler object	Inform link producer to send LAST data sent Send data_sent event message to acknowledgement handler object
Retry limit reached	Ignore event	Not applicable	Product-specific	Transition to running with acknowledgement

Table E.22 *(continued)*

Event	State			
	Not running	**Running**	**Running with acknowledgement**	**Prohibited**
Inhibit timer expires	Ignore event	Not applicable	Not applicable	If ack_active set: if ack_received, transition to running with acknowledgement, Clear ack_ received flag, else ignore event Else transition to running
Connection deleted	Not applicable	Transition to not running	Transition to not running	Transition to not running
Acknowledge_active	Set ack_active flag	Transition to running with acknowledge-ment Set ack_active flag	Ignore event	Set ack_active flag
Acknowledge_ inactive	Reset ack_active flag	Ignore event	Transition to running Reset ack_active flag	Reset ack_active flag
Connection transitions to established	If ack_active, transition to running with acknowledgement If ack_inactive, transition to running	Ignore event	Ignore event	Ignore event
NOTE This is a partial state-event matrix for a producing I/O application object. Only those states and events associated with data acknowledgement are defined. Other states and events are likely to be associated with a producing I/O application object.				

Table E.23 – State-event matrix for acknowledgement handler object

Event	State		
	Non-existent	**Inactive**	**Active**
Receive acknowledgement	Not applicable	Ignore event	Clear ack flag Forward any data to application object If all acknowledges received, clear ack timer and retry counter, send acknowledge_received event message to producing application object
Acknowledgement timer expires	Not applicable	Ignore event	Send ack-timeout event message to producing application object
Data_sent	Not applicable	Ignore event	Set ack_required flag and ack timer Clear retry counter

Table E.23 *(continued)*

Event	State		
	Non-existent	**Inactive**	**Active**
Data_resent	Not applicable	Ignore event	Set ack_required flag and ack timer. If retry limit <>0, increment retry counter If retry counter = retry_limit, send retry_limit_reached event message to producing application object
Delete	Not applicable	Transition to non-existent	Transition to non-existent
Create	Transition to Inactive	Not applicable	Not applicable
Apply_attributes	Not applicable	Verify that new connection may be added to list Pass this message to the consuming application object, if one is configured for this connection	Verify that new connection may be added to list Pass this message to the consuming application object, if one is configured for this connection
Connection transitions to established	Not applicable	Add this connection instance to the connection list (or internally flag as "acking") Pass this message to the consuming application object, if one is configured for this connection Send acknowledge_active event message to producing application transition to active	Add this connection instance to the connection list Pass this message to the consuming application object, if one is configured for this connection
Inactivity/watchdog timer expires	Not applicable	Not applicable	Internally flag as "not acking" An acknowledgement will no longer be monitored for this connection, however, it remains in the connection list Pass this event to the consuming application object, if one is configured for this connection If no "acking" connections in list, send acknowledge_inactive event to producing application and transition to inactive
Connection deleted	Not applicable	Ignore event	Remove this connection instance from the connection list Pass this event to the consuming application object, if one is configured for this connection If no "acking" connections in list, send acknowledge_inactive event to producing application and transition to inactive

Annex F
(normative)

Value ranges

The following terms are used when defining value ranges:

– **open:** value whose meaning shall be the same for all DeviceNet users;
– **manufacturer-specific:** range of values that are specific to the manufacturer of a device and which may be used to extend a device beyond the available open options;
– **object class-specific:** range of values whose meaning is defined by an object class. This range applies to service code definitions.

Class ID value ranges and meanings are given in table F.1.

Table F.1 – Class ID ranges

Range	Meaning
$00 – 63_{hex}$	Open. These are referred to as DeviceNet public class codes and are defined in annex E
$64_{hex} – C7_{hex}$	Manufacturer-specific
$C8_{hex} – FF_{hex}$	Reserved
$100_{hex} – 2FF_{hex}$	Open
$300_{hex} – 4FF_{hex}$	Manufacturer-specific
$500_{hex} – FFFF_{hex}$	Reserved

Service code value ranges and meanings are given in table F.2.

Table F.2 – Service code ranges

Range	Meaning
$00 – 31_{hex}$	Open. These are referred to as DeviceNet common services and are defined in annex A
$32_{hex} – 4A_{hex}$	Manufacturer-specific
$4B_{hex} – 63_{hex}$	Object class-specific
$64_{hex} – 7F_{hex}$	Reserved
$80_{hex} – FF_{hex}$	Invalid

Attribute ID value ranges and meanings are given in table F.3.

Table F.3 – Attribute ID ranges

Range	Meaning
$00 – 63_{hex}$	Open
$64_{hex} – C7_{hex}$	Manufacturer-specific
$C8_{hex} – FF_{hex}$	Reserved

MAC ID value ranges and meanings are given in table F.4.

Table F.4 – MAC ID range

Range	Meaning
$00 – 63_{decimal}$	MAC ID. The value 63 (decimal) shall be utilised upon initialisation of a device unless another value has been assigned

Device type value ranges and meanings are given in table F.5.

Table F.5 – Device type ranges

Range	Meaning
$00_{hex} – 63_{hex}$	Open
$64_{hex} – C7_{hex}$	Manufacturer-specific
$C8_{hex} – FF_{hex}$	Reserved
$100_{hex} – 2FF_{hex}$	Open
$300_{hex} – 4FF_{hex}$	Manufacturer-specific
$500_{hex} – FFFF_{hex}$	Reserved

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