BS EN IEC 61158-4-24:2023

BSI Standards Publication

# Industrial communication networks — Fieldbus specifications

Part 4-24: Data-link layer protocol specification — Type 24 elements

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# National foreword

This British Standard is the UK implementation of EN IEC 61158-4-24:2023. It is identical to IEC 61158-4-24:2023. It supersedes BS EN IEC 61158-4-24:2019, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/65/3, Industrial communications: process measurement and control, including fieldbus.

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English Version

# Industrial communication networks - Fieldbus specifications - Part 4-24: Data-link layer protocol specification - Type 24 elements (IEC 61158-4-24:2023)

Réseaux de communication industriels - Spécifications des bus de terrain - Partie 4-24: Spécification du protocole de la couche liaison de données - Éléments de type 24 (IEC 61158-4-24:2023)

Industrielle Kommunikationsnetze - Feldbusse – Teil 4-24: Protokollspezifikation des Data Link Layer (Sicherungsschicht) - Typ 24-Elemente (IEC 61158-4-24:2023)

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The text of document 65C/1202/FDIS, future edition 3 of IEC 61158-4-24, prepared by SC 65C "Industrial networks" of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61158-4-24:2023.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2024-02-02
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2026-05-02

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In the official version, for Bibliography, the following notes have to be added for the standard indicated:

IEC 61784-1 (series) NOTE Approved as EN IEC 61784-1 (series)

IEC 61784-2 (series) NOTE Approved as EN IEC 61784-2 (series)

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# Annex ZA
(normative)

## Normative references to international publications with their corresponding European publications

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

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cencenelec.eu.

| Publication | Year | Title | EN/HD | Year |
|---|---|---|---|---|
| IEC 61158-2 | 2023 | Industrial communication networks - Fieldbus specifications - Part 2: Physical layer specification and service definition | EN IEC 61158-2 | 2023 |
| IEC 61158-3-24 | 2023 | Industrial communication networks - Fieldbus specifications - Part 3-24: Data-link layer service definition - Type 24 elements | EN IEC 61158-3-24 | 2023 |
| ISO/IEC 7498-1 | - | Information technology - Open Systems Interconnection - Basic reference model: The basic model | - | - |
| ISO/IEC 7498-3 | - | Information technology - Open Systems Interconnection - Basic reference model: Naming and addressing | - | - |
| ISO/IEC/IEEE 8802-3 | 2021 | Telecommunications and exchange between information technology systems - Requirements for local and metropolitan area networks - Part 3: Standard for Ethernet | - | - |
| ISO/IEC 9899 | - | Information technology - Programming languages - C | - | - |
| ISO/IEC 10731 | - | Information technology - Open Systems Interconnection - Basic Reference Model - Conventions for the definition of OSI services | - | - |
| ISO/IEC 13239 | 2002 | Information technology - Telecommunications and information exchange between systems - High-level data link control (HDLC) procedures | - | - |
| ISO/IEC 19501 | 2005 | Information technology - Open Distributed Processing - Unified Modeling Language (UML) Version 1.4.2 | - | - |

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# INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

## Part 4-24: Data-link layer protocol specification – Type 24 elements

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

IEC 61158-4-24 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation. It is an International Standard.

This third edition cancels and replaces the second edition published in 2019. This edition constitutes a technical revision.

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

- addition of a new cyclic transmission mode which called "no time slot type" in Subclause 4.3.2.4;
- addition of a new frame format for no time slot type in Subclause 5.4;
- addition of a new DLE element procedure for no time slot type in Subclause 6.2.3.2.4, 6.3.3.2.2.4, 6.3.3.3.2.4;
- addition of a new DLM protcol machine for no time slot type in Subclause 7.5, 7.6; and
- spelling and grammar.

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

| Draft | Report on voting |
|---|---|
| 65C/1202/FDIS | 65C/1243/RVD |

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be …

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

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# INTRODUCTION

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

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

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

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

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent. IEC takes no position concerning the evidence, validity, and scope of this patent right.

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# INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

# Part 4-24: Data-link layer protocol specification – Type 24 elements

## 1 Scope

### 1.1 General

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

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

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

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

### 1.2 Specifications

This part of IEC 61158 provides specifies

- procedures for the timely transfer of data and control information from one data-link user entity to a peer user entity, and among the data-link entities forming the distributed datalink service provider;
- procedures for giving communications opportunities to all participating DL-entities (DLEs), sequentially and in a cyclic manner for deterministic and synchronized transfer at cyclic intervals up to 64 ms;
- procedures for giving communication opportunities available for time-critical data transmission together with non-time-critical data transmission without prejudice to the time-critical data transmission;
- procedures for giving cyclic and acyclic communication opportunities for time-critical data transmission with prioritized access;
- procedures for giving communication opportunities based on ISO/IEC/IEEE 8802-3 medium access control, with provisions for nodes to be added or removed during normal operation;
- the structure of the fieldbus DLPDUs used for the transfer of data and control information by the protocol of this document, and their representation as physical interface data units.

### 1.3 Procedures

The procedures are defined in terms of

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

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### 1.4 Applicability

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

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

### 1.5 Conformance

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

## 2 Normative references

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

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

IEC 61158-2:2023, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 61158-3-24:2023, *Industrial communication networks – Fieldbus specifications – Part 3-24: Data-link layer service definition – Type 24 elements*

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

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

ISO/IEC/IEEE 8802-3:2021, *Information technology – Telecommunications and exchange between information technology systems — Requirements for local and metropolitan area networks –Part 3: Standard for Ethernet*

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

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

ISO/IEC 13239:2002, *Information technology – Telecommunications and information exchange between systems – High-level data link control (HDLC) procedures*

ISO/IEC 19501:2005, *Information technology – Open Distributed Processing – Unified Modelling Language (UML) Version 1.4.2*

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# 3 Terms, definitions, symbols, abbreviated terms and conventions

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

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

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

## 3.1 Reference model terms and definitions

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

| | | |
|---|---|---|
| **3.1.1** | **acknowledgement** | [ISO/IEC 7498-1] |
| **3.1.2** | **correspondent (N)-entities** | [ISO/IEC 7498-1] |
| | **correspondent DL-entities (N=2)** | |
| | **correspondent Ph-entities (N=1)** | |
| **3.1.3** | **DL-address** | [ISO/IEC 7498-3] |
| **3.1.4** | **DL-protocol** | [ISO/IEC 7498-1] |
| **3.1.5** | **DL-protocol-data-unit** | [ISO/IEC 7498-1] |
| **3.1.6** | **DL-service-data-unit** | [ISO/IEC 7498-1] |
| **3.1.7** | **DLS-user** | [ISO/IEC 7498-1] |
| **3.1.8** | **DLS-user-data** | [ISO/IEC 7498-1] |
| **3.1.9** | **Event** | [ISO/IEC 19501] |
| **3.1.10** | **layer-management** | [ISO/IEC 7498-1] |
| **3.1.11** | **primitive name** | [ISO/IEC 7498-1] |
| **3.1.12** | **Reset** | [ISO/IEC 7498-1] |
| **3.1.13** | **Segmenting** | [ISO/IEC 7498-1] |
| **3.1.14** | **State** | [ISO/IEC 19501] |
| **3.1.15** | **state machine** | [ISO/IEC 19501] |
| **3.1.16** | **systems-management** | [ISO/IEC 7498-1] |
| **3.1.17** | **Transition** | [ISO/IEC 19501] |
| **3.1.18** | **(N)-entity** | [ISO/IEC 7498-1] |
| | **DL-entity (N=2)** | |
| | **Ph-entity (N=1)** | |
| **3.1.19** | **(N)-layer** | [ISO/IEC 7498-1] |
| | **DL-layer (N=2)** | |

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**Ph-layer (N=1)**

**(N)-service** [ISO/IEC 7498-1]

**DL-service (N=2)**

**Ph-service (N=1)**

**(N)-service-access-point** [ISO/IEC 7498-1]

**DL-service-access-point (N=2)**

**Ph-service-access-point (N=1)**

## 3.2 Service convention terms and definitions

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

**3.2.1 confirm (primitive)**

**3.2.2 DL-service-primitive**

**3.2.3 DL-service-provider**

**3.2.4 DL-service-user**

**3.2.5 indication (primitive)**

**3.2.6 request (primitive)**

**3.2.7 requestor**

**3.2.8 response (primitive)**

## 3.3 Common terms and definitions

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

**3.3.1**
**acyclic transmission**
non-periodic exchange of telegrams

**3.3.2**
**C1 master**
one of the network device types that initiates and controls cyclic transmission

**3.3.3**
**C1 message**
message communication that C1 master operates as initiator to exchange messages with slave or C2 master

**3.3.4**
**C2 master**
one of the network device types that has the function of monitoring all process data transmitted through the network and can initiate message communication

**3.3.5**
**C2 message**
message communication that C2 master operates as initiator to exchange messages with the slave or the C1 master

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**3.3.6**
**cyclic transmission**
periodic exchange of telegrams

**3.3.7**
**data**
generic term used to refer to any information carried over a fieldbus

**3.3.8**
**device**
physical entity connected to the fieldbus composed of at least one communication element (the network element) and which has a control element and/or a final element (transducer, actuator, etc.)

**3.3.9**
**event driven mode**
transmission mode for the application layer protocol of the communication Type 24 in which a transaction of command-response-exchanging arises as user's demands

**3.3.10**
**frame**
synonym for DLPDU

**3.3.11**
**initiator**
network device that initiates the exchange of process data or message

**3.3.12**
**interface**
shared boundary between two functional units, defined by functional characteristics, signal characteristics, or other characteristics as appropriate

**3.3.13**
**input data**
process data sent by the slave and received by the C1 master

**3.3.14**
**message**
ordered series of octets intended to convey information

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

**3.3.15**
**monitor slave**
slave that has the function of monitoring all process data transmitted through the network

**3.3.16**
**network**
set of nodes connected by some type of communication medium, including any intervening repeaters, bridges, routers and lower-layer gateways

**3.3.17**
**node**
<protocol> single DL-entity as it appears on one local link

**3.3.18**
**node**
<networking> end-point of a link in a network or a point at which two or more links meet

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**3.3.19**
**output data**
process data sent by the C1 master and received by the slaves

**3.3.20**
**protocol**
convention about the data formats, time sequences, and error correction in the data exchange of communication systems

**3.3.21**
**real-time communication**
transfer of data in real-time

**3.3.22**
**receiving DLS-user**
DL-service user that acts as a recipient of DL-user-data

Note 1 to entry: A DL-service user can be concurrently both a sending and receiving DLS-user.

**3.3.23**
**responder**
network device that responds process data or message after it has been initiated by initiator

**3.3.24**
**send data with acknowledge**
data transfer service with acknowledge of reception from corresponding DLE

**3.3.25**
**send data without acknowledge**
data transfer service without acknowledge of reception from corresponding DLE

**3.3.26**
**slave**
one of the network device type that accesses the medium only after it has been initiated by C1 maser or C2 master

**3.3.27**
**sending DLS-user**
DL-service user that acts as a source of DL-user-data

**3.3.28**
**station**
node

**3.3.29**
**topology**
physical network architecture with respect to the connection between the network devices of the communication system

**3.3.30**
**transmission cycle**
fixed time period of cyclic transmission

**3.3.31**
**time slot**
time period reserved so that initiator and responder can exchange one frame respectively

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### 3.4 Symbols and abbreviations

| | |
|---|---|
| DA | Destination address |
| DL- | Data-link layer (as a prefix) |
| DLE | DL-entity (the local active instance of the data-link layer) |
| DLL | DL-layer |
| DLM | DL-management |
| DLME | DL-management entity (the local active instance of DL-management) |
| DLMS | DL-management service |
| DLPDU | DL-protocol-data-unit |
| DLS | DL-service |
| DLSAP | DL-service-access-point |
| DLSDU | DL-service-data-unit |
| FIFO | First-in first-out (queuing method) |
| ID | Identifier |
| OSI | Open systems interconnection |
| PDU | Protocol data unit |
| Ph- | Physical layer (as a prefix) |
| PhE | Ph-entity (the local active instance of the physical layer) |
| PhL | Ph-layer |
| PHY | Physical layer device (specified in ISO/IEC/IEEE 8802-3) |
| QoS | Quality of service |
| RT | Real-time |
| SAP | Service access point |
| SDU | Service data unit |

### 3.5 Additional Type 24 symbols and abbreviations

| | |
|---|---|
| ACK | Acknowledge |
| C1MSG | C1 message |
| C2MSG | C2 message |
| I/O | Input and/or output |
| MSG | Message |
| Rx | Receive |
| SDA | Send data with acknowledge |
| SDN | Send data without acknowledge |
| SM | State machine |
| Tcycle | Transmission cycle |
| Tslot | Time slot |
| Tx | Transmit |

### 3.6 Common conventions

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

The service model, service primitives, and time-sequence diagrams used are entirely abstract descriptions; they do not represent a specification for implementation.

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Service primitives, used to represent service user/service provider interactions (see ISO/IEC 10731), convey parameters that indicate information available in the user/provider interactions.

This document uses a tabular format to describe the component parameters of the DLS primitives. The parameters that apply to each group of DLS primitives are set out in tables throughout the remainder of this document. Each table consists of up to six columns, containing the name of the service parameter, and a column each for those primitives and parameter-transfer directions used by the DLS:

- the request primitive's input parameters;
- the indication primitive's output parameters;
- the response primitive's input parameters;
- the confirm primitive's output parameters.

NOTE The request, indication, response and confirm primitives are also known as requestor.submit, acceptor.deliver, acceptor.submit, and requestor.deliver primitives, respectively (see ISO/IEC 10731).

One parameter (or part of it) is listed in each row of each table. Under the appropriate service primitive columns, a code is used to specify the type of usage of the parameter on the primitive and parameter direction specified in the column:

M parameter is mandatory for the primitive.

U parameter is a User option, and can be provided or not depending on the dynamic usage of the DLS-user. When not provided, a default value for the parameter is assumed.

C parameter is conditional upon other parameters or upon the environment of the DLS-user.

(blank) parameter is never present.

Some entries are further qualified by items in brackets. These may be a parameter-specific constraint:

(=) parameter is semantically equivalent to the parameter in the service primitive to its immediate left in the table.

In any particular interface, not all parameters need to be explicitly stated. Some may be implicitly associated with the primitive.

In the diagrams which illustrate these interfaces, dashed lines indicate cause-and-effect or time-sequence relationships, and wavy lines indicate that events are roughly contemporaneous.

## 3.7 Additional Type 24 conventions

### 3.7.1 Primitive conventions

The following notation, a shortened form of the primitive classes defined in 3.2, is used in the figures.

req request primitive

ind indication primitive

cnf confirm primitive (confirmation)

### 3.7.2 State machine conventions

The protocol sequences are described by means of state machines.

In state diagrams, states are represented as boxes and state transitions are shown as arrows.

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Names of states and transitions of the state diagram correspond to the names in the state table. The textual listing of the state transitions is structured as shown in Table 1.

**Table 1 – State transition descriptions**

| No. | Current state | Event /condition =>action | Next state |
|---|---|---|---|
| | | | |

The description of state machine elements are shown in Table 2.

**Table 2 – Description of state machine elements**

| Description element | Meaning |
|---|---|
| No | Number of the transition. |
| Current state,<br>Next state | Names of the originating state and the target state of transition. |
| Event | Name or description of the trigger event that fires the transition. |
| / conditions | Boolean expression, which shall be true for the transition to be fired. |
| =>action | List of assignments and service or function invocations. The action should be atomic. The preceding "=>" is not part of the action. |
| NOTE "/ conditions" can be omitted. | |

The conventions used in the state machines are shown in Table 3.

**Table 3 – Conventions used in state machines**

| Convention | Meaning |
|---|---|
| + - * / | Arithmetic operators |
| := | Value of an item on the left is replaced by value of an item on the right. If an item on the right is a parameter, it comes from the primitive shown as an input event. |
| = | A logical condition to indicate an item on the left is equal to the item on the right. |
| < | A logical condition to indicate an item on the left is less than the item on the right. |
| > | A logical condition to indicate an item on the left is greater than the item on the right. |
| <= | A logical condition to indicate an item on the left is less than or equal to the item on the right. |
| >= | A logical condition to indicate an item on the left is greater than or equal to the item on the right. |
| <> | A logical condition to indicate an item on the left is not equal to the item on the right. |
| && | Logical "AND" |
| \|\| | Logical "OR" |

# 4 Overview of DL-protocol

## 4.1 Characteristic feature of the DL-protocol

Table 4 shows the characteristic features of the DL protocol of Type 24.

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**Table 4 – Characteristic features of the fieldbus data-link protocol**

| Profiles | Description |
|---|---|
| Station type and max. stations | -C1 master (active station with bus access control, 1 station (mandatory))<br>-C2 master (active station with restricted bus access control, (optional))<br>-Slave (passive stations without bus access control, max.127) |
| Station addressing | 1 to 255 (255 = global address for broad-cast messages), 8 bit-width address extension for integrated device |
| Transmission cycle | 15,625 µs to 64 ms |
| DLSDU size | 0 octets to 64 octets |
| Transmission characteristic | -Cyclic data exchange and cyclic event, synchronized with accurate cycle time (jitter below 1 µs)<br>-Max 62 times (n times/1 station) retry within cycle time<br>-Acyclic message transmission |

There are three types of stations, the C1 master, the C2 master and the slave. Data exchange is executed between one master station (C1 master or C2 master) and N slave stations. This protocol supports 2 communication modes, cyclic transmission and acyclic transmission.

In the cyclic transmission mode, transmission is executed cyclically with an accurate period. The transmission cycle is set by the C1 master to a value within a range of 15,625 [µs] to 64 [ms]. Since the set value of the transmission cycle is specific to the transmission line, all of the connected slaves shall support that value. It is not permitted to set different transmission cycle values for the slaves connected in the same network.

The transmission cycle has the I/O data exchange band to transmit process data and the message communication band to transmit message. The protocol machine in the C1 master controls transmission sequence in the cyclic transmission mode. The time period for a master station to exchange with one slave station is called time slot. There are two types of communication sequence using time slot, one is "fixed-width time slot type" whose time slot width is the same for all stations, and the other is "configurable time slot type" whose time slot can be defined for each station. As another communication sequence, "no time slot type", which does not use time slot, is provided. All stations shall use the same-data-length frame when fixed-width time slot type. The width of the time slot is static in both types, and the value is set by the DL-management during initialization. Once the cyclic communication starts, it shall not be changed.

The Acyclic transmission mode is used by the DLS-user that operates in the event driven mode. In the acyclic transmission mode, transmissions are executed sporadically. The same transmission sequence and message communication can be executed in the acyclic transmission, as in the cyclic transmission mode without fixing the transmission cycle.

### 4.2 DL layer component

The DL layer is composed of three sublayers, the CTC (Cyclic transmission control), the SRC (Send Receive Control) and the DLM (Data-link management). The SRC is positioned at lower layer of the CTC and the DLM covers both the CTC sublayer and the SRC sublayer. The data-link layer component is show in Figure 1.

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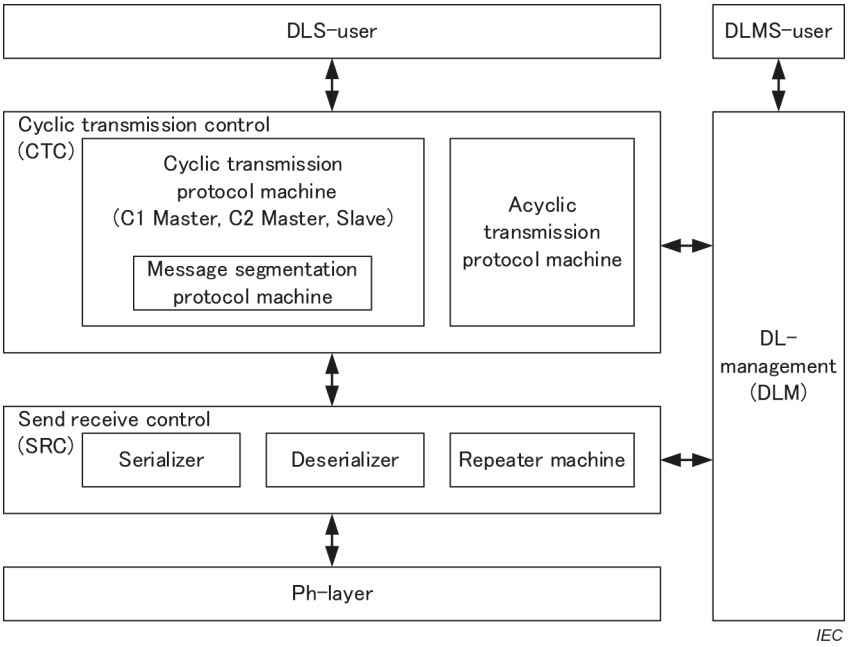


**Figure 1 – Data-link layer component**

### 4.2.1 Cyclic transmission control (CTC)

This is a sublayer that builds the DLPDU and executes a protocol machine. It has 2 communication modes, i.e. cyclic transmission mode and acyclic transmission mode. The CTC executes either of them according to a request from the DLMS user.

### 4.2.2 Send receive control (SRC)

The SRC sends or receives frames by request of the CTC sublayer. It is serialized or de-serialized according to corresponding PHY. When the SRC implements two or more PHY port, the SRC provides frame repeat function between the implemented PHY ports.

### 4.2.3 DL-management

This is a sublayer that configures the DLE operation by setting the internal variables and manages errors detected by each sublayer.

## 4.3 Timing sequence

### 4.3.1 Overview

There are two types of transmission mode, the cyclic transmission mode and the acyclic transmission mode. The communication sequence has three types. "Fixed-width time slot type" is described in 4.3.2.1, "configurable time slot type" is described in 4.3.2.2, and "no time slot type" is described in 4.3.2.4.

The width of the time slot is static for both types, and the value is set by the DL-management during initialization. Once cyclic communication starts, it shall not be changed.

### 4.3.2 Cyclic transmission mode

#### 4.3.2.1 Fixed-width time slot type

##### 4.3.2.1.1 Overview

Figure 2 shows the transmission sequence of fixed-width time slot type. In this type, all time slots are same period.

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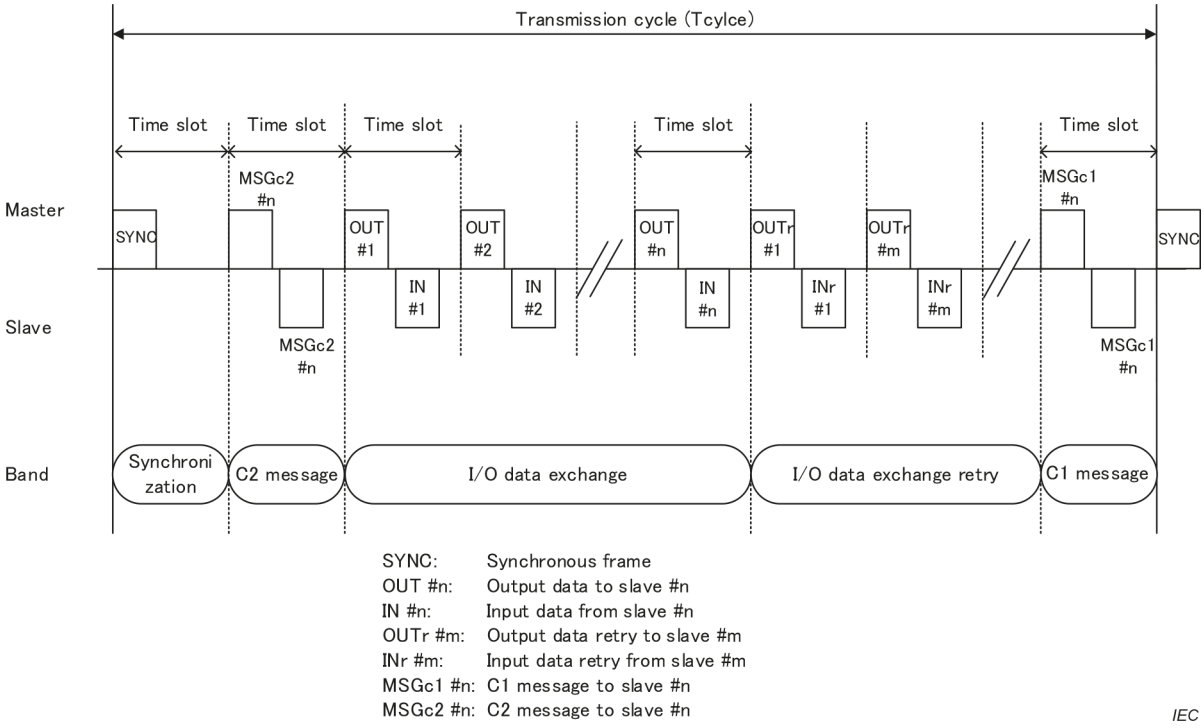


**Figure 2 – Timing chart of fixed-width time slot type cyclic communication**

#### 4.3.2.1.2 Detailed description of communication band

##### 4.3.2.1.2.1 Synchronization

This is the band through which the C1 master broadcasts a synchronous frame to the slave and the C2 master. One time slot shall be allocated to this band. Within this band, only the transition of the synchronous frame from the C1 master is allowed; the slave and the C2 master are prohibited from transmitting any frame.

##### 4.3.2.1.2.2 C2 message

This is an optional band for a message transmission (C2 message transmission) where the C2 master is the client (primary station) and the C1 master or slave is the server (secondary station). One time slot is allocated to this band, and request and response is transmitted once, respectively.

##### 4.3.2.1.2.3 I/O data exchange

This is the band in which the C1 master exchanges the I/O data with all the slaves that are connected to the network. The time slots of the number of slaves shall be allocated to this band. The C1 master and one slave shall execute the I/O data exchange once within one time slot.

The I/O data exchange retry band is optional. When the I/O data exchange retry band is configured in the transmission cycle, the C1 master shall create a retry list of the slave that failed the I/O data exchange.

##### 4.3.2.1.2.4 I/O data exchange retry

The I/O data exchange retry band is an optional band that the C1 master retries the I/O data exchanges according to the retry list. The C1 master can re-execute the I/O exchange with the retry target slave that has been registered into the retry list in the I/O data exchange band. In this band, some time slots are allocated before cyclic transmission started.

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The C1 master can retry according to the registered order of the retry list for up to the number of the allocated time slots. The DLE shall quit retry when it uses all allocated time slots even if a slave that is waiting for retry is registered in the retry list.

#### 4.3.2.1.2.5 C1 message

This is an optional band for a message transmission (C1 message transmission) where the C1 master is the client (initiator) and the C2 master or the slave is the server (responder). One time slot is configured in this band. This band is configured to be shared with the I/O data exchange retry band. When this band is shared and used for the I/O data exchange retry, the C1 message transmission shall be postponed to the C1 message band of the next transmission cycle.

### 4.3.2.1.3 Estimation of cycle time

The transmission cycle of the fixed-width slot type $T_{cycle}$ is calculated as the sum of the bandwidths described in the following formula.

$$T_{cycle}=T_{sync}+T_{C2msg}+T_{io}+T_{retry}+T_{C1msg} \quad (1)$$

where

$T_{sync}$ is the Sync band;

$T_{C2msg}$ is the C2 message band;

$T_{io}$ is the I/O data exchange band;

$T_{retry}$ is the I/O data exchange retry band;

$T_{C1msg}$ is the C1 message band.

The width of each band shall be allocated with an integral multiple of time slots. The formula shown above can be transformed by indicating the time slot with $T_{slot}$ the number of slave stations connected to the network with $N$, and the number of retry with $N_r$.

$$T_{cycle}=T_{slot}+T_{slot}+N\times T_{slot}+N_r\times T_{slot}+T_{slot}= (N+N_r+3)\times T_{slot} \quad (2)$$

The I/O data exchange retry band and the C1 message band are configured to be shared. When they are shared, the formula becomes:

$$T_{cycle}=(N+N_r+2)\times T_{slot} \quad (3)$$

And, the I/O data exchange retry band, the C1 message band and the C2 message band are optional. When the configuration doesn't assign all of them, the transmission cycle is minimum and is calculated as shown in the following formula:

$$T_{cycle}=(N+1)\times T_{slot} \quad (4)$$

Time slot $T_{slot}$ can be calculated as shown in the following formula:

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$$T_{slot}=\max\left(T_{tr_c}(n)+T_{dly}(n)+T_{gap}+T_{tr_r}(n)+T_{dly}(n)+T_{gap}\right)= 2\times\max\left(T_{tr_c}(n)+T_{dly}(n)+T_{gap}\right) \quad (5)$$

where

$T_{tr_c}(n)$ is the output (command) transmission time from C1 master to the slave #$n$;

$T_{tr_r}(n)$ is the input (response) transmission time from slave #$n$ to C1 master, it is equal to $T_{tr_c}(n)$ in case of the fixed-width time slot type;

$T_{gap}$ is the gap between the frames;

$T_{dly}(n)$ is the frame transmission delay time between C1 master and slave #$n$.

#### 4.3.2.2 Configurable time slot type

##### 4.3.2.2.1 Overview

Figure 3 shows the transmission sequence of configurable time slot type. In this type, the width of time slots that are allocated to exchange the data one by one between the master and the slave is different for each slave. The DLE manages the residual time of the transmission cycle by using the width of the time slots configured for each slave by the DLMS user. Details of each transmission band are described in the following subclauses.

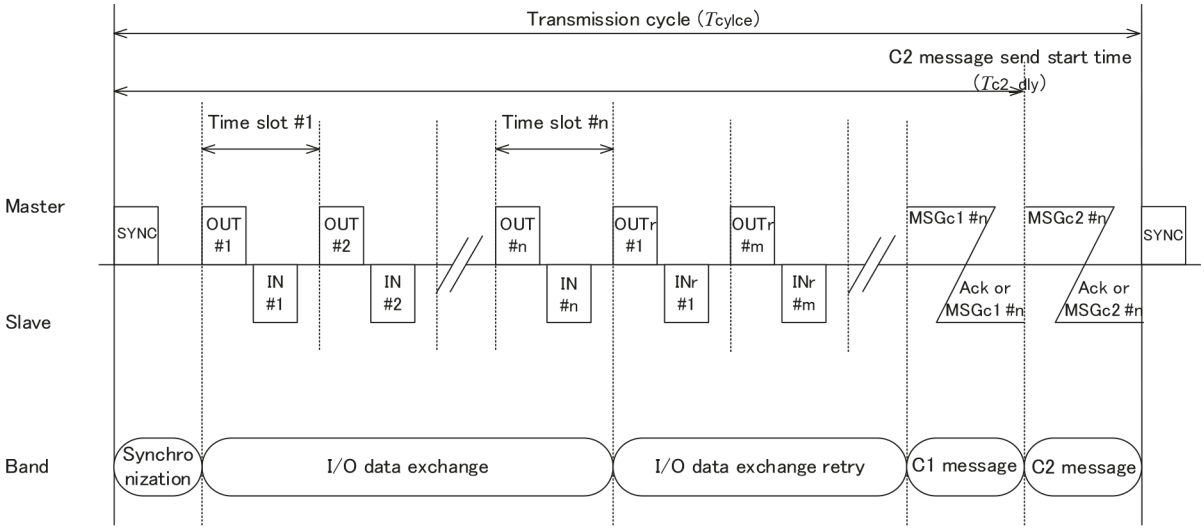


**Figure 3 – Timing chart of configurable time slot type cyclic communication**

##### 4.3.2.2.2 Detailed description of communication phase

###### 4.3.2.2.2.1 Synchronization

See 4.3.2.1.2.1.

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#### 4.3.2.2.2.2 IO data exchange

This is the band where the C1 master executes the I/O data exchange with all slaves connected to the network. The width of this band shall be set in the C1 master before starting cyclic transmission. The C1 master and one slave execute a I/O data exchange which consists of a pair of input and output for each other in each time slot.

When the I/O data exchange retry band which is optional is configured in the transmission cycle, the C1 master shall register the slaves that have failed the I/O data exchange within this band into the retry list as re-transmission targets within the succeeding the I/O data exchange retry band.

#### 4.3.2.2.2.3 IO data exchange retry

This band is basically the same as the case of fixed-width time slot (see 4.3.2.1.2.4). Subclause 4.3.2.2.2.3 describes the differences.

The width of this band shall be set in the C1 master before starting the cyclic transmission. The C1 master can execute the retry for the slaves registered in the retry list in the order of registration, and when the retry succeeds, the C1 master clears the registration. Before executing retry, the C1 master shall compare the time required to complete the I/O data exchange with the slave and the residual time until the end of this band (until C2 message starts). If the residual time is longer than the required time, the C1 master shall execute the retry. If the residual time is equal to or shorter than the required time, the C1 master shall end this band.

When the retry that is executed for a registered the slave does not complete successfully, the C1 master shall clear the registration and then register the slave again at the end of the retry list. The C1 master can repeat retry for the same slaves within the residual time of the band. When the retries for all of the retry targets in the retry list are executed once, the C1 master can execute the retry according to the registered order of the retry list again. The C1 master shall end the band when all of the slaves are cleared from the retry list.

#### 4.3.2.2.2.4 C1 message

This is an optional band for a message transmission (C1 message transmission) where the C1 master is the client (primary station) and the C2 master or the slave is the server (secondary station). The residual time from the end of the I/O data exchange retry band to the start of the C2 message transmission is assigned to this band.

The C1 master can execute the C1 message transmission within the residual time. The C1 master can repeat the C1 message transmission that consists of one pair of request and response within this band. However, the C1 master shall not execute the C1 message transmission if there is no residual time enough for one pair of transmission.

This band is configured to be shared with the I/O data exchange retry band. When this band is shared and used for the I/O data exchange retry, the C1 message transmission shall be postponed to the C1 message band of the next transmission cycle.

#### 4.3.2.2.2.5 C2 message

This is an optional band for a message transmission (C2 message transmission) where the C2 master is the client (primary station) and the C1 master or the slave is the server (secondary station). The start time of this band shall be set both in the C1 master and the C2 master before starting cyclic transmission.

The C2 master can execute the C2 message transmission within the allocated bandwidth. The C2 master can repeat the C2 message transmission that consists of one pair of request and

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response within this band. However, the C2 master shall not execute the C2 message transmission if there is no residual time enough for one pair of transmission.

This band is configured to be shared with the I/O data exchange retry band and the C1 message band. When this band is shared and used for the I/O data exchange retry or the C1 message, the C2 message shall be postponed to the C2 message band of the next transmission cycle. When this band is shared and the C1 master has finished the I/O data exchange retry and the C1 message before the start time of this band, the C1 master shall send a message token to the C2 master. After the C2 master receives the message token, the C2 master can execute the C2 message transmission immediately.

#### 4.3.2.2.3 Estimation of cycle time

In order for all multiple slaves to synchronize with the C1 master, the C1 master shall measure the transmission delay time of each slave during initialization. The measured delay time shall be locally retained by the C1 master and each slave.

Based on the measured transmission delay time, the C1 master can calculate the response monitoring time and the delay time of cyclic event for each slave to match cyclic event timing in the system.

The cyclic event delay time ($T_{idly}$ in Figure 4) is delivered with the synchronous frame (SYN frame in the Figure 4). The C1 master and each slave generate a cyclic event according to the cyclic event delay time and the transmission delay time retained locally. As a result, cyclic event occurs at the same time throughout the system.

By processing the output data and the input data simultaneously in all slaves at the cycle event timing, the system can operate synchronously.

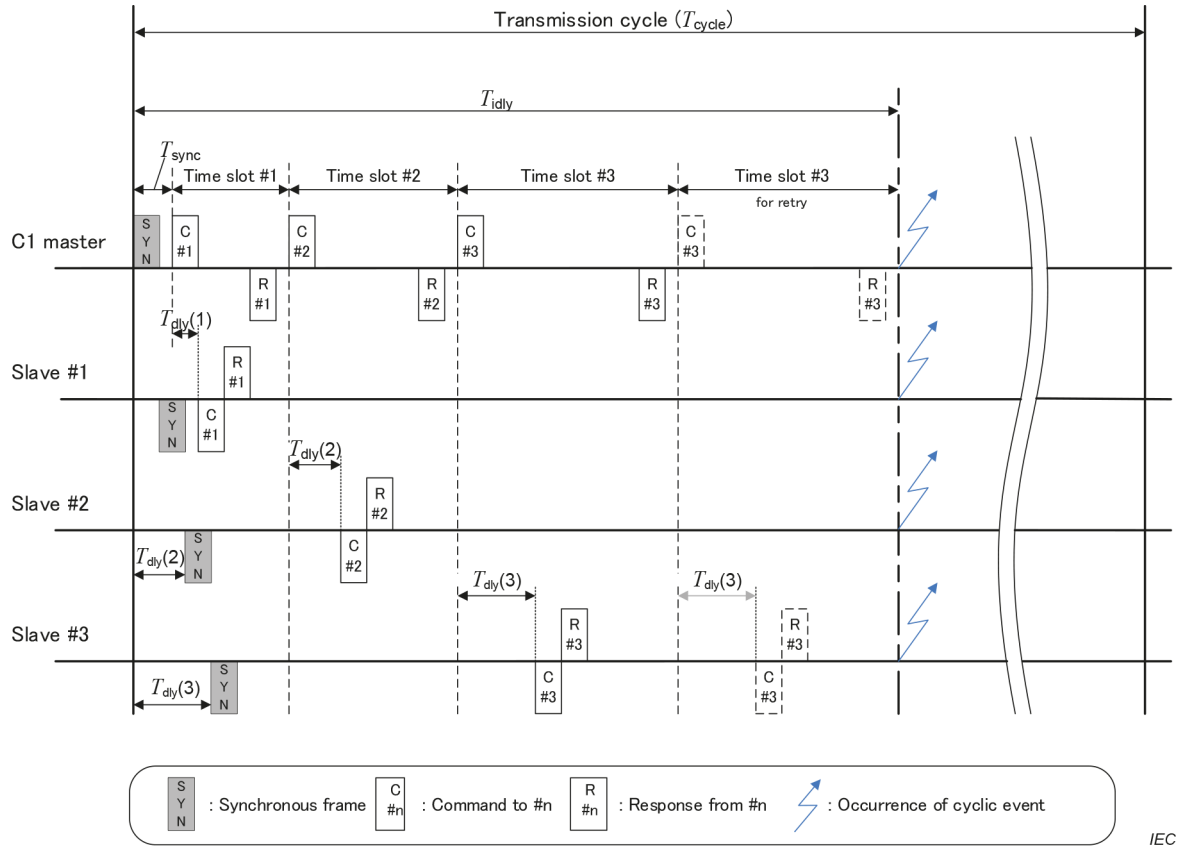


**Figure 4 – Schematic diagram of cyclic event occurrence**

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The transmission cycle of the variable time slot type $T_{cycle}$ is calculated as an aggregation of the band described in 4.3.2.2.1, as shown in the following formula:

$$T_{cycle}=T_{sync}+T_{io}+T_{retry}+T_{C1msg}+T_{C2msg} \quad (6)$$

where

$T_{sync}$ is the Synchronization band;

$T_{io}$ is the I/O data exchange band;

$T_{retry}$ is the I/O data exchange retry band;

$T_{c1msg}$ is the C1 message band;

$T_{c2msg}$ is the C2 message band.

The I/O data exchange retry band and the C1 message band are configured to be shared. When they are shared, the formula becomes:

$$T_{cycle}=T_{sync}+T_{io}+\max\left(T_{retry},T_{C1msg}\right)+T_{C2msg} \quad (7)$$

And, the I/O data exchange retry band, the C1 message band and the C2 message band are optional. When the configuration doesn't assign all of them, the transmission cycle is minimum and is calculated as shown in the following formula:

$$T_{cycle}=T_{sync}+T_{io} \quad (8)$$

The calculation method for the bands mentioned above is shown in the following.

- Synchronization band

  The Sync band $T_{sync}$ is calculated as follows: where $T_{tr_s}$ is the transmission time of the synchronous frame, and $T_{gap}$ is the gap between the frames:

$$T_{sync}=T_{tr_s}+T_{gap} \quad (9)$$

- I/O data exchange band

  The I/O data exchange band $T_{io}$ is calculated as follows: where $N$ is the number of slaves, $T_{tr_c}(n)$is the output (command) transmission time from the C1 master to the slave #$n$, $T_{tr_r}(n)$ is the input (response) transmission time from the slave #$n$, $T_{dly}(n)$is the frame transmission delay time between the C1 master and the slave #$n$, and $T_{gap}$ is the inter-packet gap:

$$T_{io}=\sum_{n=1}^{N}\left(T_{tr_c}(n)+T_{dly}(n)+T_{gap}+T_{tr_r}(n)+T_{dly}(n)+T_{gap}\right)= \sum_{n=1}^{N}\left(T_{tr_c}(n)+T_{tr_r}(n)+2\times T_{dly}(n)\right)+2\times N\times T_{gap} \quad (10)$$

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The I/O data exchange retry band $T_{retry}$ is calculated as follows: where $N_r$ is the maximum number of the retry:

$$T_{retry}=\sum_{r=1}^{N_r}\left(T_{tr_c}(r)+T_{dly}(r)+T_{gap}+T_{tr_r}(r)+T_{dly}(r)+T_{gap}\right)= \sum_{r=1}^{N_r}\left(T_{tr_c}(r)+T_{tr_r}(r)+2\times T_{dly}(r)\right)+2\times N_r\times T_{gap} \quad (11)$$

- C1 message band

  The C1 message band $T_{c1msg}$ is calculated as follows: where $T_{tr_clc}(m_1)$ is the request transmission time from the primary station (C1 master) to the secondary station $m_1$ ($m_1$ is the station number of slaves or the C2 master that becomes the secondary station), $T_{tr_clr}(m_1)$ is the response transmission time from the secondary station to the primary station, $T_{dly}(m_1)$ is the transmission delay between the primary station and the secondary station, $T_{c1msg}$ is the number of the C1 messages:

$$T_{c1msg}=N_{c1msg}\times\left(T_{tr_c1c}(m_1)+T_{dly}(m_1)+T_{gap}+T_{tr_c1r}(m_1)+T_{dly}(m_1)+T_{gap}\right)= N_{c1msg}\times\left(T_{tr_c1c}(m_1)+T_{tr_c1r}(m_1)+2\times T_{dly}(m_1)+2\times T_{gap}\right) \quad (12)$$

- C2 message band

  The C2 message band $T_{c2msg}$ is calculated as follows: where $T_{tr_c2c}(m_2)$ is the request transmission time from the primary station (C2 master) to the secondary station $m_2$($m_2$ is the station number of the slave or the C1 master that becomes the secondary station), $T_{tr_c2r}(m_2)$ is the response transmission time from the secondary station to the primary station, $T_{dly}(m_2)$ is the transmission delay between the primary station and the secondary station, $N_{c2msg}$ is the number of the C2 messages:

$$T_{c2msg}=N_{c2msg}\times\left(T_{tr_c2c}(m_2)+T_{dly}(m_2)+T_{gap}+T_{tr_c2r}(m_2)+T_{dly}(m_2)+T_{gap}\right)= N_{c2msg}\times\left(T_{tr_c2c}(m_2)+T_{tr_c2r}(m_2)+2\times T_{dly}(m_2)+2\times T_{gap}\right) \quad (13)$$

#### 4.3.2.3 Timing relationship between cyclic transmission and data processing

Subclause 4.3.2.3 explains the timing relationship between the cyclic transmission and the data processing by using Figure 5. In cycle #1, the slaves latch input and make the input data to be sent. The input data that each slave made is transmitted to the C1 master in cycle #2. Though it is received by the C1 master, it is not processed by the C1 master at this time. The C1 master starts to process it at the top of the cycle #3. Therefore, the delay from the timing of the slave's latched input to the timing of the master processing it is two transmission cycles.

Similarly, the output data that the C1 master made at cycle #3 is transmitted to all the slaves, slave by slave, in cycle #4. Though it is received by each slave in cycle #4, it is not processed by the slave at this time. All the slaves start to process it all together at the top of cycle #5. Therefore, the delay from the timing of the master's making the output data to the timing of the slave processing it is two transmission cycles, that is same as the input data.

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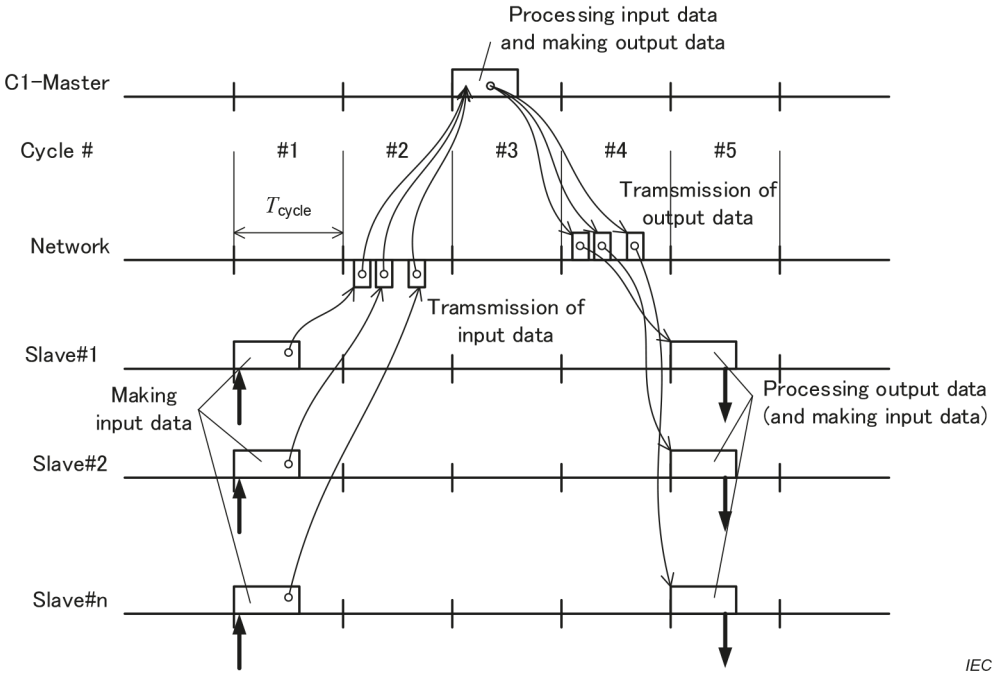


NOTE Output data and input data are transmitted in every cycle, but these drawings are omitted in this figure to explain easily. Data processing by C1 master and slaves in every cycle are also omitted.

**Figure 5 – Timing relationship between cyclic transmission and data processing**

#### 4.3.2.4 No time slot type

##### 4.3.2.4.1 Overview

Figure 6 shows the transmission sequence of no time slot type. The C1 master of this type sends one frame of output data. After certain time from or at the same time with the timing of receiving of this output data, the C2 master and the slave respond with the input data to the C1 master. As the input data size differs according to slave, the time width for sending the input data also differs according to slave. Details of the timing of receiving of output data and the timing of responding of input data are as described in 4.3.2.4.3.

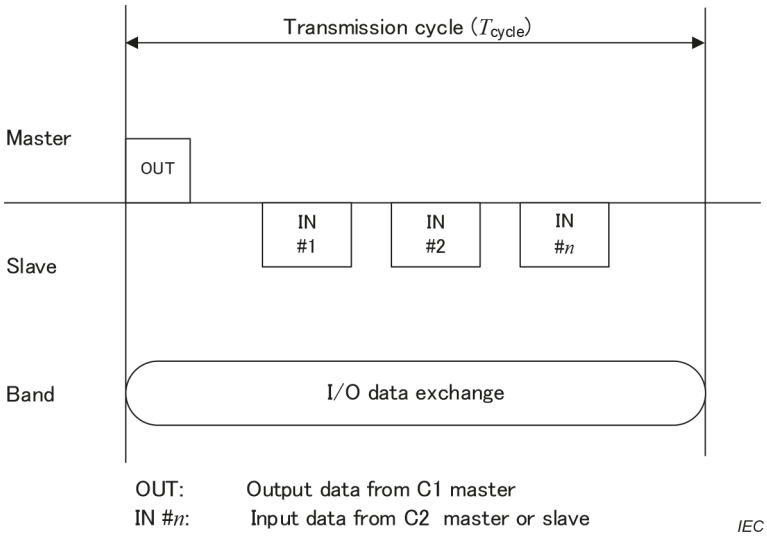


**Figure 6 – Timing chart of no time slot type cyclic communication (Master send common address)**

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Also, the basic transmission cycle of no time slot type can be set as the integer multiple of basic transmission cycle for each slave ($T_{cyc}$). This is the communication with multiple transmission cycles. For the communication with multiple transmission cycles, "individual transmission cycle multiple ($T_{cc_mul}$)" and "individual transmission position number ($T_{cc_pos}$)" can be set for each slave (see IEC 61158-3-24, 5.3.2.2.2, Table 14).

$T_{cc_mul}$ indicates the transmission cycle in which the slave returns a response. $T_{cc_pos}$ indicates the timing at which transmission cycle the slave returns a response. The C1 master shall send the command frame with the Cycle Counter setting, which is to be incremented for each transmission cycle. The slaves shall divide the Cycle Counter value with $T_{cc_mul}$ value set for the slaves and output division remainder. If the division remainder match with $T_{cc_pos}$, they shall respond to the C1 master. Figure 7 shows the timing chart when the setting of all slaves is $T_{cc_mul}$ = 1 and $T_{cc_pos}$ = 0. All slaves can respond with the input data to every transmission cycle.

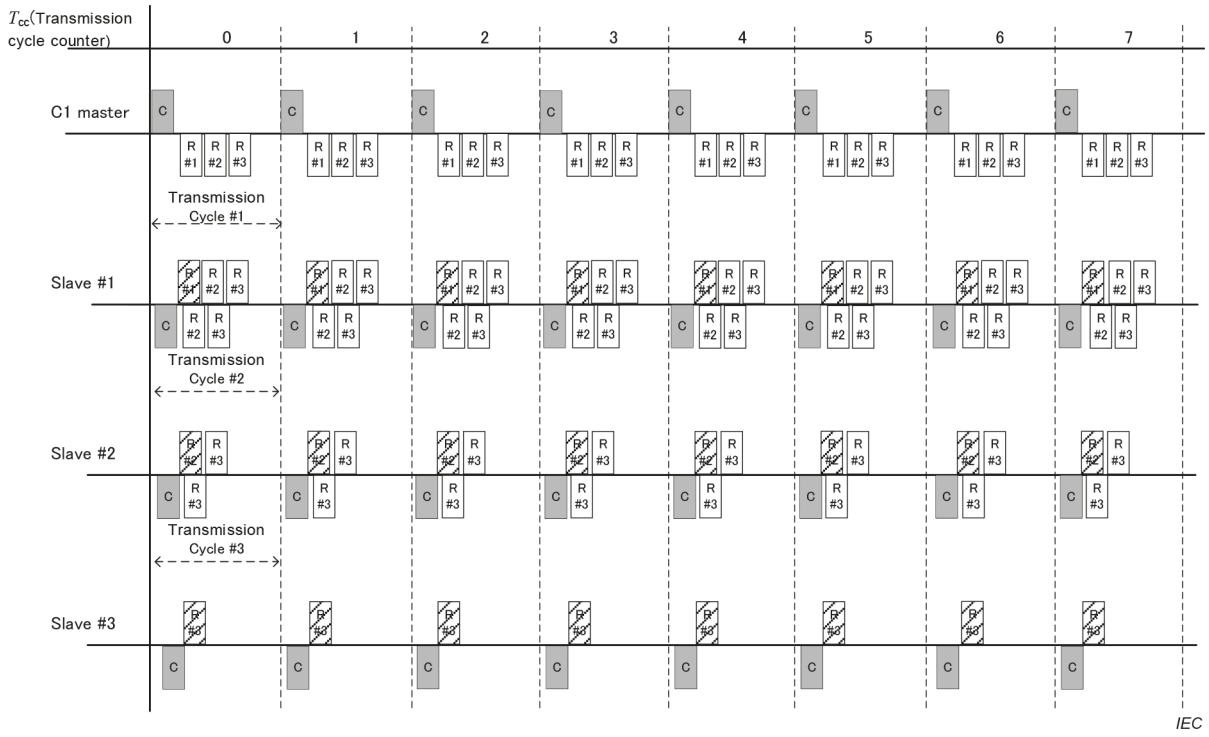


**Figure 7 – Timing chart for multiple transmission cycle setting**

Figure 8 shows the timing chart when individual transmission cycles are set for each slave. As Slave #1 has the setting of $T_{cc_mul}$ = 1 and $T_{cc_pos}$ = 0, it returns the response (R#1) for all transmission cycles. As Slave #2 has the setting of $T_{cc_mul}$ = 2 and $T_{cc_pos}$ = 1, it returns the response (R#2) once every two transmission cycles and at the second transmission cycle. As Slave #3 has the setting of $T_{cc_mul}$ = 4 and $T_{cc_pos}$ = 2, it returns the response (R#3) once every four transmission cycles and at the third transmission cycle.

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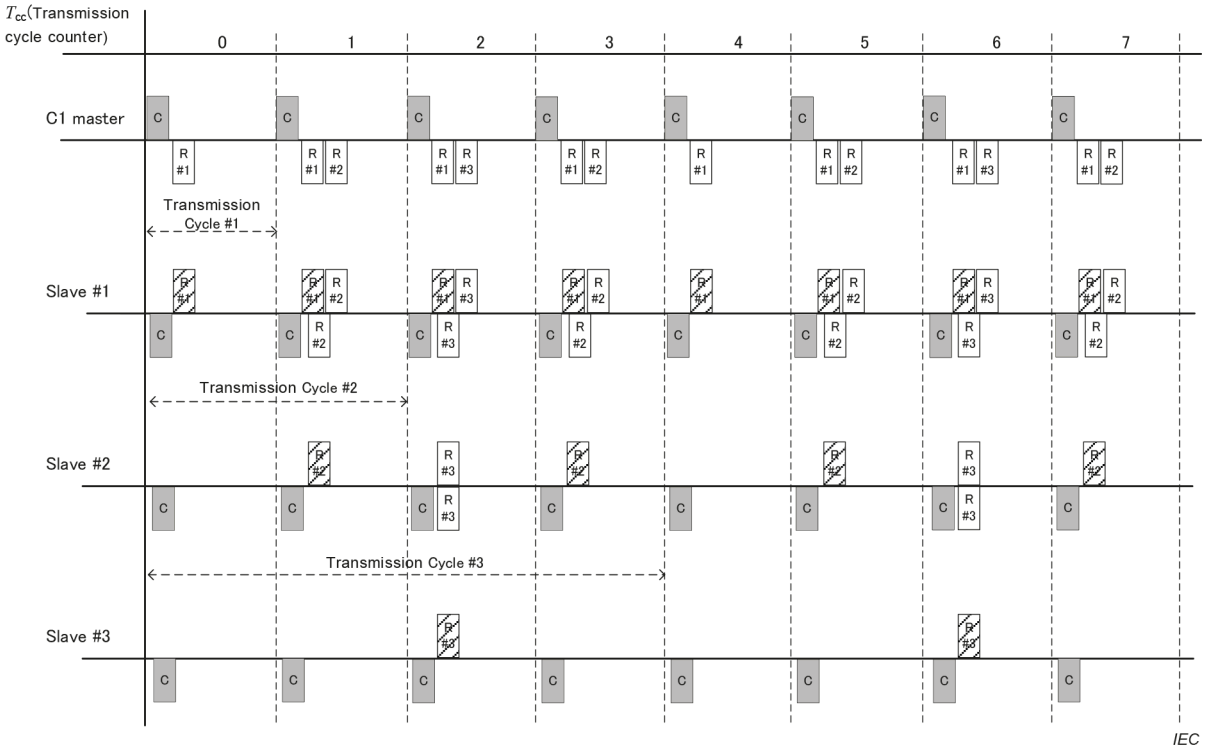


**Figure 8 – Timing chart for multiple transmission cycle setting igure title**

#### 4.3.2.4.2 Detailed description of I/O data exchange band

The C1 master exchanges the I/O data with all the C2 master and slaves that are connected to the network. The C1 master should transmit the output data and all slaves should respond with the input data.

The C1 master can send the output data by designating the C2 master or the slave in the address field. The designated C2 master or the slave can respond with the input data corresponding to the output data and other slaves whose address does not match can return the input data.

#### 4.3.2.4.3 Estimation of cycle time

The cycle time of no time slot type is defined in the following formula:

$$T_{cycle}=T_{io} \tag{14}$$

where

$T_{io}$ is the I/O data exchange band.

Figure 9 shows the schematic diagram for estimating the cycle time for this type. In Figure 9, the nodes for the C1 master, the C2 master, the number of slaves, and each connection node are defined as follows:

where

$N$ is the total number of nodes for connecting the C1 master, the C2 master and slave;

$\#n$ is the node number assigned by the C1 master;

$L$ is the total number of C2 masters;

$\#l$ is the C2 master number;

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*M* is the total number of slaves;

*#m* is the slave number.

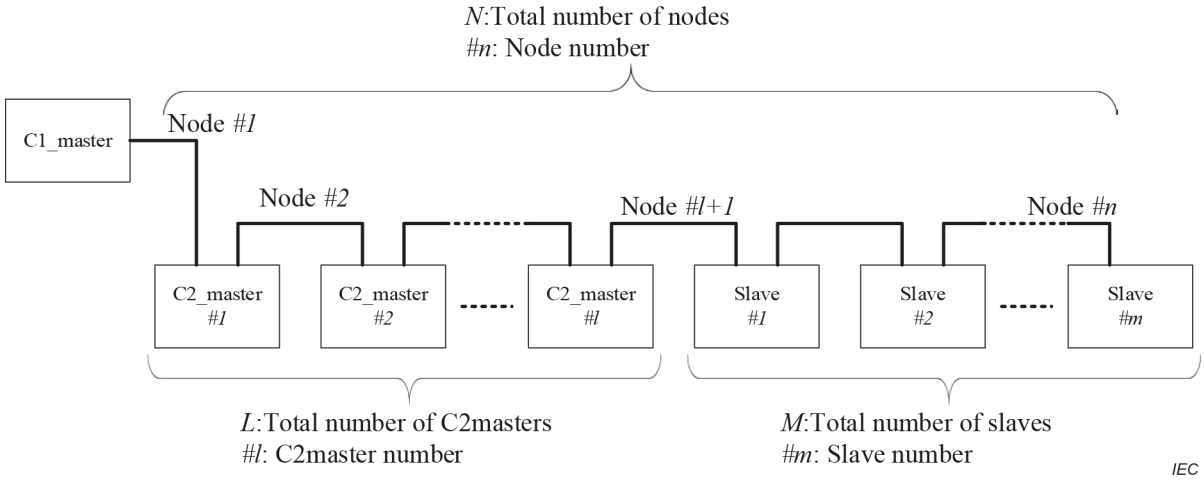


**Figure 9 – Schematic diagram for connection**

The formula for the estimation of transmission cycles of this type is available for the following two operations. One is when the response with the input data is made after certain time interval from the timing of receiving by multiple C2 masters and multiple slaves of the output data. The other is when the response with the input data is made at the same time as the timing of receiving by multiple C2 masters and multiple slaves.

Figure 10 shows the timing chart when each slave responds with the input data after certain time interval from the timing of receiving of the output data.

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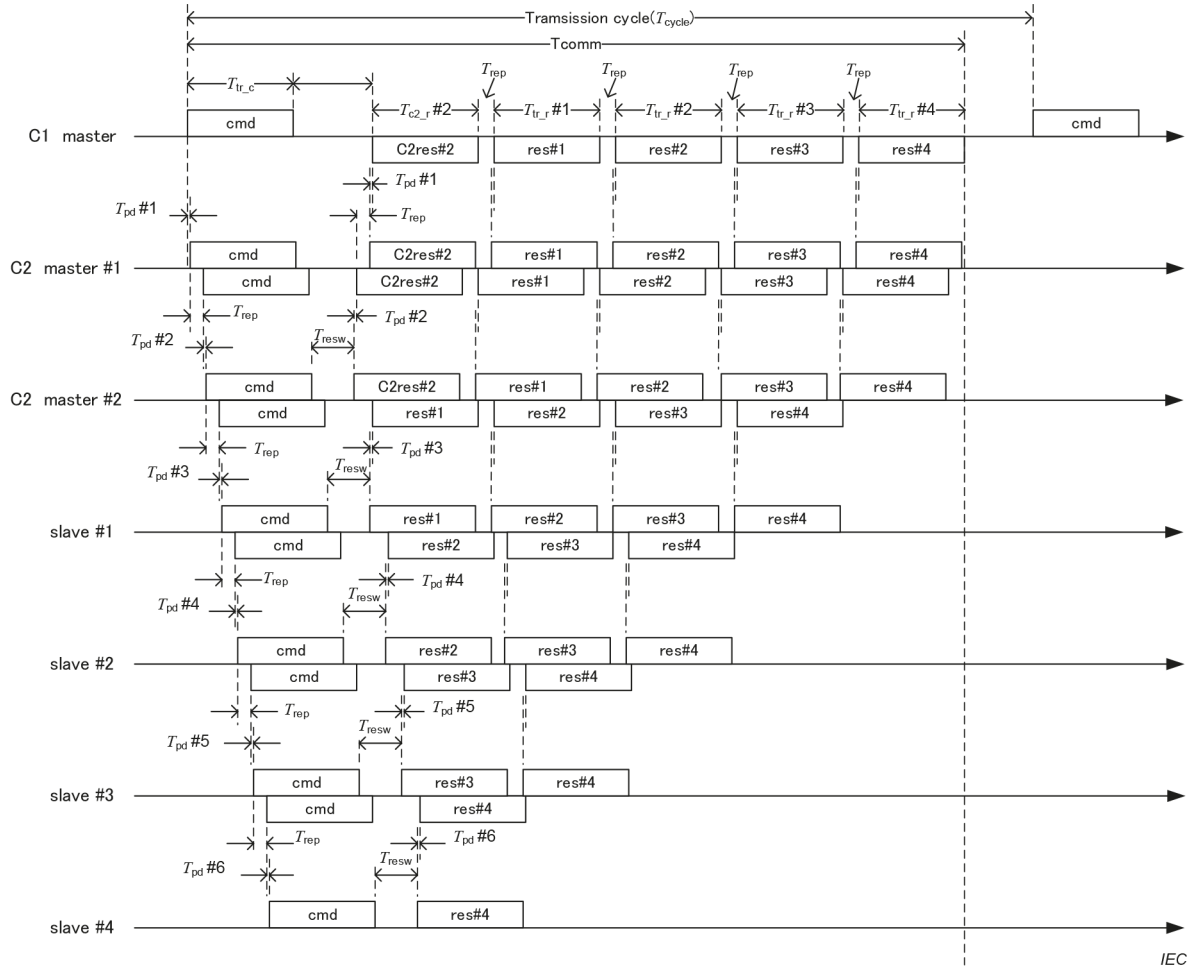


**Figure 10 – Schematic diagram of INPUT data response timing at the same interval**

With Figure 10 as the operating condition, the Formula (15) is given as follows:

$$T_{cycle}=2\times\sum_{n=1}^{N}\left(T_{pd}(\#n)+T_{rep}\times(n-1)\right)-T_{pd}(N)+T_{tr_c}+T_{resw}+T_{c2_r}(\#l)+\sum_{m=1}^{N-L}\left(T_{tr_r}(\#m)\right) \quad (15)$$

where

$T_{pd}(\#n)$ is the propagation delay time of the $n$-th node;

$T_{rep}$ is the output (command) or the input (response) repeating time in the slave;

$T_{tr_c}$ is the output (command) transmission time to send from the C1 master to all slaves;

$T_{resw}$ is the response waiting time of the C2 master or the slave to the output (command) from the C1 master;

$T_{c2_r}(\#l)$ is the input (response) transmission time from the $l$–th C2 master to the C1 master;

$T_{tr_r}(\#m)$ is the input (response) transmission time from the $m$–th slave to the C1 master.

Next, Figure 11 shows the timing chart when each slave responds with the input data at the same time as the timing of receiving of the output data.

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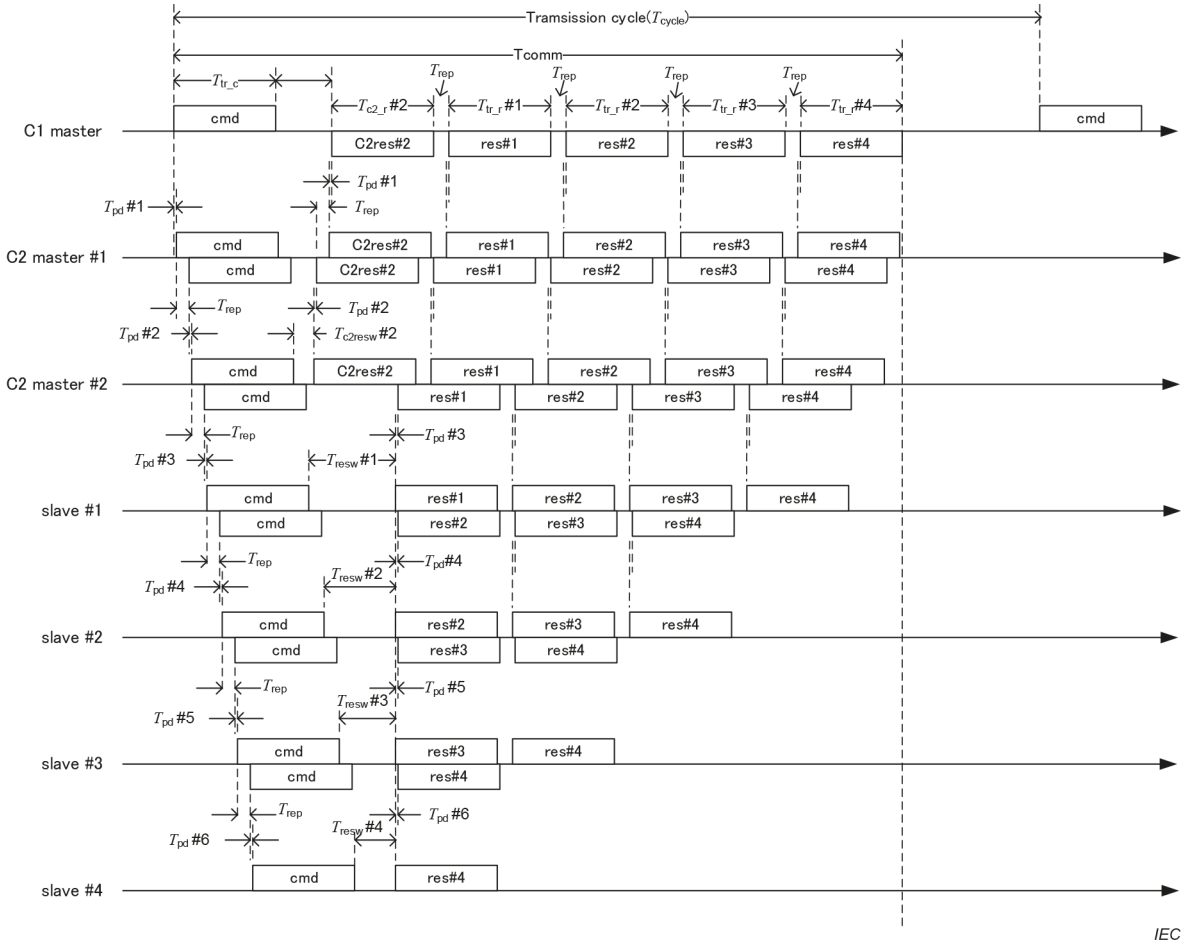


**Figure 11 – Schematic diagram of INPUT data response timing at the same time**

With Figure 11 as the operating condition, the Formula (16) is given as follows:

$$T_{cycle}=2\times\sum_{n=1}^{N}\left(T_{pd}(\#n)+T_{rep}\times(n-1)\right)-T_{pd}(N)+T_{tr_c}+T_{C2resw}(\#l)+T_{c2_r}(\#l)+\sum_{m=1}^{N-L}\left(T_{tr_r}(\#m)\right) \quad (16)$$

where

$T_{pd}(\#n)$ is the propagation delay time of the $n$-th node;

$T_{rep}$ is the output (command) or the input (response) repeating time in the slave;

$T_{tr_c}$ is the output (command) transmission time to send from the C1 master to all slaves;

$T_{c2resw}(\#l)$ is the response waiting time of the $l$–th C2 master to the output (command) from the C1 master;

$T_{c2_r}(\#l)$ is the input (response) transmission time from the $l$–th C2 master to the C1 master;

$T_{tr_r}(\#m)$ is the input (response) transmission time from the $m$–th slave to the C1 master.

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#### 4.3.2.5 Timing relationship between cyclic transmission and data processing for no time slot type

The timing relationship between cyclic transmission and data processing for no time slot type is as described in 4.3.2.3. However, the C1 master of no time slot type consolidates the output data as one block of data.

### 4.3.3 Acyclic transmission mode

The acyclic transmission can be used in a system that does not require real-time communication or cyclical data exchange. In the acyclic transmission mode, it is possible to execute the same transmission sequence as a cyclic transmission mode without fixing the transmission cycle. Although the C2 message communication is also possible, the DLS-user shall execute the arbitration of the transmission timing. In the acyclic transmission mode, the data length is fixed at 64 octets.

Since the acyclic transmission does not use the synchronous frame, slaves execute processing of the output data sent by the master and processing of the data to send the input data at its own timing. The slaves do not operate simultaneously.

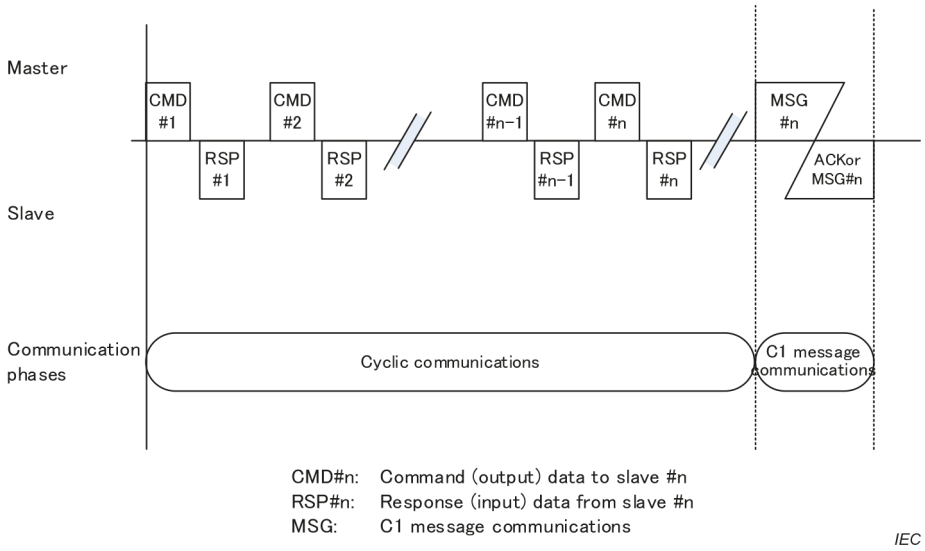


**Figure 12 – Timing chart example of acyclic communication**

## 4.4 Service assumed from the PhL

### 4.4.1 General requirement

There are two types of Ph-service which DLE requires. One is defined in IEC 61158-2, Type 24 and the other is defined in ISO/IEC/IEEE 8802-3:2021, Clause 6.

Both types require the following interface elements:

- Transmit Machine,
- Receive Machine,
- Serializer,
- Deserializer.

### 4.4.2 DL_Symbols

The PhL Interface Data Units present at the DLL-PhL interface shall be the DL_symbols. The DL_symbol shall have one of the following values:

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- ZERO corresponds to a binary "0";
- ONE corresponds to a binary "1".

#### 4.4.3 Assumed primitives of the PhS

The PhS is assumed to provide the following two categories of primitives to the Type 24 DL-protocol.

- Service primitives for transmitting and receiving frames to / from other peer DLEs.
- Service primitives that provide information needed by the local DLE to perform the media access functions.

The assumed primitives of the PhS are grouped into these two categories:

- Transfer of Data to the corresponding DLE
  - PLS_DATA request
  - PLS_DATA indication
- Indication from the local PhL
  - PLS_CARRIER indication
  - PLS_SIGNAL indication
  - PLS_DATA_VALID indication

### 4.5 Local parameters, variables, counters, timers

#### 4.5.1 Overview

This specification uses the DLS-user request parameters P(…) and local variables V(…) as a means of clarifying the effect of certain actions and the conditions under which those actions are valid, local timers T(…) as a means of monitoring actions of the distributed DLS-provider and of ensuring a local DLE response to the absence of those actions. It also uses local queues Q(…) as a means of ordering certain activities, of clarifying the effects of certain actions, and of clarifying the conditions under which those activities are valid.

Unless otherwise specified, at the moment of their creation or of DLE activation:

- all variables shall be initialized to their default value, or to their minimum permitted value if no default is specified;
- all timers shall be initialized to inactive;
- all queues shall be initialized to empty.

DL-management can change the values of configuration variables.

#### 4.5.2 Variables, parameters, counters and timers to support DLE function

##### 4.5.2.1 V(MA), P(MA)

This variable is used by the CTC to record station address of this station. This variable shall be implemented by all stations. Its range is 1 to $2^{16} - 1$. When the station adopts short format of the DLPDU, the lower 8 bits of this variable is effective. When the station adopts short format II of the DLPDU, the lower 5 bits of this variable are effective.

##### 4.5.2.2 V(Tcycle), P(Tcycle)

This variable is used by the CTC to record transmission period of cyclic communication. This variable shall be implemented by all stations. The value of time depends on V($T_{\text{unit}}$). Its range is 1 to 64 000.

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#### 4.5.2.3 V(Nmax_slaves), P(Nmax_slaves)

This variable is used by the CTC to record the number of connectable slave stations. Its range is 1 to 62.

#### 4.5.2.4 V(Cyc_sel), P(Cyc_sel)

This variable is used by the DLM to record the selection of transmission mode, which is cyclic or acyclic. The value is listed at Table 5.

**Table 5 – List of the values of the variable Cyc_sel**

| Value | Symbol | Description |
|---|---|---|
| 0 | CMode_Cyclic | Cyclic transmission mode |
| 1 | CMode_Acyclic | Acyclic transmission mode |

#### 4.5.2.5 V(Nmax_dly_cnt), P(Nmax_dly_cnt)

This variable is used by the DLM to record maximum-measurement-count, which limits the number of delay measurement execution. This variable is implemented only by the C1 master adopts configurable time slot. Its default value is 2. Its range is 2 to 31.

#### 4.5.2.6 V(IO_sz), P(IO_sz)

This variable is used by the CTC to hold and designate the data size of send and receive frame, which is transferred in the I/O data exchange band. Its range is 0 to 64. When the CTC adopts fixed-width time slot, its value shall be same for all stations.

#### 4.5.2.7 V(Pkt_sz), P(Pkt_sz)

This variable is used by message segmentation machine to record the message packet size of the cyclic transmission. Its range is 4 to 500. When CTC adopts fixed-width time slot, its value shall be equal to V(IO_sz).

#### 4.5.2.8 V(Nmax_retry), P(Nmax_retry)

This variable is used by the CTC to record maximum-retry-count, which limits the number of retries in the I/O data exchange retry band. This variable is implemented only by the C1 master. Its default value is 0, meaning retry are not permitted. Its range is 0 to 62.

#### 4.5.2.9 V(Tslot), P(Tslot)

This variable is used by the CTC to hold and designate the value of the timeout time for the I/O data exchange to each station. This variable shall be implemented by the C1 master and the C2 master. Its range is 0 to less than V($T_{\text{cycle}}$). The time that a set value indicates depends on V($T_{\text{unit}}$). When the CTC adopts fixed-width time slot, its value shall be same for all stations.

#### 4.5.2.10 V(Tunit), P(Tunit)

This variable is used by the CTC to record the unit of a set value of the variable concerning time, when the CTC adopts configurable time slot. Table 6 shows its range. This variable shall be implemented only by the CTC which adopts configurable time slot. The CTC which adopts fixed-width time slot shall not this variable, and shall use 250 ns as time unit for all variables concerning time. The CTC that adopts no time slot shall use 1 ns as time unit for all variables concerning time.

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**Table 6 – List of the values of the variable Tunit**

| Value | Definition | Tcycle |
|---|---|---|
| 0 | 10 ns | 31,25 µs to 500 µs |
| 1 | 100 ns | More than 500 µs to 4 ms |
| 2 | 1 µs | More than 4 ms to 64 ms |
| NOTE Value 0 is default. | | |

#### 4.5.2.11 V(Tidly), P(Tidly)

This variable is used by the CTC to record the timing of event, which is issued periodically to synchronize the DLS-user. This variable shall be implemented by all stations, which adopt configurable time slot. The value is delay time from the start of cyclic transmission. Its range is 0 to less than V($T_{cycle}$). The time that a set value indicates depends on V($T_{unit}$).

#### 4.5.2.12 V(Tc2_dly), P(Tc2_dly)

This variable is used by the CTC to record the timing to start the C2 message communication. This variable shall be implemented by the C1 master and the C2 master, which adopt configurable time slot. The value is delay time from the end of cyclic transmission. Its range is 0 to less than V($T_{cycle}$). The time that a set value indicates depends on V($T_{unit}$).

#### 4.5.2.13 V(Tmsg), P(Tmsg)

This variable is used by the CTC to record the time period for message communication. This variable shall be implemented by the C1 master and the C2 master. Its range is 0 to less than V($T_{cycle}$). The time that a set value indicates depends on V($T_{unit}$). When the CTC adopts fixed-width time slot, its value shall be same for all stations.

#### 4.5.2.14 V(Twrpt)

This variable is used by the SRC to record the time period for transmission delay measurement. This variable shall be implemented by the C2 master and the slave. Its range is V($T_{slot}$) × 3 to less than 64 ms. The default value is 500 µs. The time that a set value indicates depends on V($T_{unit}$).

#### 4.5.2.15 V(IO_MAP), P(IO_MAP)

This variable is used by the DLM and the CTC to record the information of the slaves and the C2 master which to be connected in the network. See IEC 61158-3-24, 5.3.2.2.13 for the details.

#### 4.5.2.16 V(Sts_STI), P(Sts_STI)

This variable is used by the DLM to hold the connection status of the stations which to be connected in the network. See IEC 61158-3-24, 5.3.3.2.2.1 for the details.

#### 4.5.2.17 V(Sts_Err), P(Sts_Err)

This variable is used by the DLM to hold the error factor which occurred in the DLE.

#### 4.5.2.18 V(Fc2msg)

This variable is used by the CTC to hold the presence of the C2 message communication band in cyclic transmission mode. This variable shall be implemented by the C1 master and the C2 master. Its value is 0 or 1. The value shall be set to 1 when the C2 message communication band is assigned, and set to 0 when it is not assigned.

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#### 4.5.2.19 V(Nslave)

This variable is used by the CTC to hold and designate slave number, which is being processed in the current time slot. This variable shall be implemented by the C1 master and the C2 master. Its range is 0 to V(Nmax_slaves). The value is reset to zero at the start of each cycle of the cyclic transmission. And it is incremented when the I/O data exchange to a slave is executed.

#### 4.5.2.20 V(Nretry)

This variable is used by the CTC to hold and designate the element of retry list, which is being processed in the current time slot. The value is reset to zero at the beginning of each transmission cycle. And it is incremented when the I/O data exchange to a slave is fault, and decremented when the I/O data exchange retry is executed.

#### 4.5.2.21 V(Nrest_slot)

This variable is used by the CTC to hold and designate the number of rest time slot for retry within the end of this cycle. Its range is 0 to V(Nmax_retry). This variable shall be implemented by the C1 master. The value is decremented in the range of V(Nmax_retry) to 0.

#### 4.5.2.22 V(Ndly_cnt)

This variable is used by the DLM to hold and designate the count of executed delay measurement. This variable shall be implemented by the C1 master, which adopt configurable time slot. The value is reset to zero at the start of each cycle of cyclic transmission, and incremented when delay measurement is executed. Its range is 0 to V(Nmax_dly_cnt).

#### 4.5.2.23 V(PDUType)

This variable is used by the CTC and the DLM to hold and designate the selection of the DLPDU type, from Basic format DLPDU. Short format DLPDU, or Short format II. When the DLE adopts each of them, it is not required to implement this variable. The value is listed at Table 7.

**Table 7 – List of the values of the variable PDUType**

| Value | Symbol | Description |
|---|---|---|
| 0 | PDUBasic | Basic format DLPDU |
| 1 | PDUShort | Short format DLPDU |
| 2 | PDUShort II | Short format II DLPDU |

#### 4.5.2.24 V(SlotType)

This variable is used by the CTC and the DLM to hold and designate the selection of time slot type, which is fixed-width or configurable. When the DLE adopts each of them, it is not required to implement this variable. The value is listed at Table 8.

**Table 8 – List of the values of the variable SlotType**

| Value | Symbol | Description |
|---|---|---|
| 0 | TSFixed | Fixed-width time slot |
| 1 | TSConfig | Configurable time slot |

#### 4.5.2.25 V(Nms_1), V(Nms_2)

This variable is used by the CTC to hold the number of segmentations to be sent in the message communication using basic format of the DLPDU. The suffix "_1" and "_2" show the band of the

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