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Ersatz für
DIN EN 61158-4-24:2015-08
Siehe Anwendungsbeginn

**Industrielle Kommunikationsnetze –
Feldbusse –
Teil 4-24: Protokollspezifikation des Data-Link Layer
(Sicherungsschicht) – Typ 24-Elemente
(IEC 61158-4-24:2019);
Englische Fassung EN IEC 61158-4-24:2019, nur auf CD-ROM**

Industrial communication networks –
Fieldbus specifications –
Part 4-24: Data-link layer protocol specification – Type 24 elements
(IEC 61158-4-24:2019);
English version EN IEC 61158-4-24:2019, only on CD-ROM

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 61158-4-24:2019);
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Anwendungsbeginn

Anwendungsbeginn für die von CENELEC am 2019-05-23 angenommene Europäische Norm als DIN-Norm ist 2020-08-01.

Für DIN EN 61158-4-24:2015-08 besteht eine Übergangsfrist bis 2022-05-23.

Nationales Vorwort

Vorausgegangener Norm-Entwurf: E DIN EN 61158-400:2017-12.

Dieser Entwurf betrifft auch die Normen DIN EN IEC 61158-4-2:2020-08, DIN EN IEC 61158-4-3:2020-08, DIN EN IEC 61158-4-4:2020-08, DIN EN IEC 61158-4-12:2020-08, DIN EN IEC 61158-4-19:2020-08, DIN EN IEC 61158-4-21:2020-08 und DIN EN IEC 61158-4-25:2020-08.

Für dieses Dokument ist das nationale Arbeitsgremium K 956 „Industrielle Kommunikation“ der DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN und VDE (www.dke.de) zuständig.

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Da sich die Benutzer der vorliegenden Norm der englischen Sprache als Fachsprache bedienen, wird die Englische Fassung der EN IEC 61158-4-24 veröffentlicht. Zu deren Abschnitt 1, der den Anwendungsbereich festlegt und Abschnitt 3 (außer Unterabschnitte 3.1, 3.2, 3.4, 3.5, 3.6 und 3.7), der die Begriffe festlegt, wurde eine Übersetzung angefertigt und als informativer Nationaler Anhang NA der vorliegenden Norm hinzugefügt. Für die meisten der verwendeten Begriffe existieren keine gebräuchlichen deutschen Benennungen, da sich die deutschen Anwender in der Regel ebenfalls der englischen Benennungen bedienen. Diese Norm steht nicht in unmittelbarem Zusammenhang mit Rechtsvorschriften und ist nicht als Sicherheitsnorm anzusehen.

Das Original-Dokument enthält Bilder in Farbe, die in der Papierversion in einer Graustufen-Darstellung wiedergegeben werden. Elektronische Versionen dieses Dokuments enthalten die Bilder in der originalen Farbdarstellung.

Ein Feldbus ist ein digitaler serieller Datenbus für die Kommunikation zwischen Geräten der industriellen Automatisierungstechnik wie beispielsweise Messeinrichtungen, Stellgliedern, Reglern und speicherprogrammierbaren Steuerungen. Die Normen der Reihe DIN EN IEC 61158 legen eine Anzahl von Feldbus-Protokolltypen fest. Die vorliegende Norm legt das Protokoll des Data-Link Layer für die einzelnen Typen fest.

Änderungen

Gegenüber DIN EN 61158-4-24:2015-08 wurden folgende Änderungen vorgenommen:

- a) redaktionelle Änderungen.

Frühere Ausgaben

DIN EN 61158-4-24: 2015-08

Nationaler Anhang NA (informativ)

Auszugsweise Übersetzung

Reihenfolge und Inhalt der folgenden Abschnitte sind identisch mit denen in den jeweiligen Abschnitten der Englischen Fassung.

EINLEITUNG

Dieser Teil von IEC 61158 gehört zu einer Normenreihe, die zur Erleichterung der Verbindung von Komponenten von Automatisierungssystemen erstellt wurde. Es ist mit anderen Normen der Reihe verbunden, wie durch das in IEC 61158-1 beschriebene „dreischichtige“ Feldbus-Referenzmodell definiert.

Das Datenverbindungsprotokoll stellt den Datenverbindungsdienst bereit, indem es die Dienste nutzt, die in der physikalischen Schicht verfügbar sind. Das vorrangige Ziel dieses Dokuments ist es, eine Reihe von Regeln für die Kommunikation zu erstellen, die sich auf die Verfahren beziehen, die von den Peer Data-Link Entities (DLE) zum Zeitpunkt der Kommunikation durchzuführen sind. Diese Regeln für die Kommunikation sollen eine stabile Grundlage für die Weiterentwicklung bilden, damit sie einer Vielzahl von Zwecken dienen können:

- a) als Leitfaden für Implementierer und Konstrukteure;
- b) zur Verwendung bei der Prüfung und Beschaffung von Ausrüstung;
- c) als Teil einer Vereinbarung über die Zulassung von Systemen in der offenen Systemumgebung;
- d) als eine Erweiterung des Verständnisses von zeitkritischer Kommunikation innerhalb der OSI.

Diese Norm befasst sich insbesondere mit der Kommunikation und dem Zusammenwirken von Sensoren, Effektoren und anderen Automatisierungsgeräten. Durch die Verwendung dieses Dokuments zusammen mit anderen Normen, die innerhalb der OSI- oder Feldbus-Referenzmodelle vorhanden sind, können andernfalls inkompatible Systeme in beliebiger Kombination zusammenarbeiten.

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US 7769935	[YE]	MASTER SLAVE COMMUNICATION SYSTEM AND MASTER
JP 4683346		SLAVE COMMUNICATION METHOD
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1 Anwendungsbereich

1.1 Allgemeines

Der Data-Link Layer stellt grundlegende zeitkritische Messaging-Kommunikationen zwischen Geräten in einem Automatisierungsumfeld bereit.

Dieses Protokoll stellt Kommunikationsmöglichkeiten für alle teilnehmenden Data-Link-Instanzen bereit:

- a) synchron startend zyklisch, entsprechend einem vorab festgelegten Plan oder
- b) azyklisch, wie durch jede dieser Data-Link-Instanzen angefordert.

Somit kann dieses Protokoll als eines charakterisiert werden, das zyklischen oder azyklischen Zugang asynchron bereitstellt, aber mit einem synchronen Neustart jedes Zyklus.

1.2 Spezifikationen

Dieses Dokument legt fest:

- a) Verfahren für den rechtzeitigen Transfer von Daten und Steuerinformationen von einer Data-Link-Benutzerinstanz zu einer Peer-Benutzerinstanz und unter den Data-Link-Instanzen, die den verteilten Data-Link-Dienstanbieter bilden;
- b) Verfahren zum Erteilen von Kommunikationsmöglichkeiten an alle teilnehmenden DL-Instanzen (DLEs), sequentiell und zyklisch für deterministischen und synchronisierten Transfer in zyklischen Intervallen bis 64 ms;
- c) Verfahren zum Erteilen von Kommunikationsmöglichkeiten, die für zeitkritische Datenübertragung zusammen mit nicht zeitkritischer Datenübertragung ohne Nachteil für die zeitkritische Datenübertragung verfügbar sind;
- d) Verfahren zum Erteilen von zyklischen und azyklischen Kommunikationsmöglichkeiten für zeitkritische Datenübertragung mit vorrangigem Zugriff;
- e) Verfahren zum Erteilen von Kommunikationsmöglichkeiten basierend auf ISO/IEC/IEEE 8802-3 Medium Access Control mit Bestimmungen für während Normalbetrieb hinzuzufügende oder zu entfernende Knoten;
- f) die Struktur der Feldbus-DLPDU, die für den Transfer von Daten und Steuerinformationen durch das Protokoll dieses Dokuments verwendet werden, und deren Darstellung als physische Schnittstelleneinheiten.

1.3 Verfahren

Die Verfahren sind definiert hinsichtlich:

- a) der Interaktionen zwischen Peer-DL-Instanzen über den Austausch von Feldbus-DLPDU;
- b) der Interaktionen zwischen einem DL-Dienst-(DLS, DL-service)-Anbieter und einem DLS-Benutzer in demselben System über den Austausch von DLS-Primitiven;
- c) der Interaktionen zwischen einem DLS-Anbieter und einem Ph-Dienstanbieter in demselben System über den Austausch von Ph-Dienstprimitiven.

1.4 Anwendbarkeit

Diese Verfahren sind anwendbar auf Kommunikationsvorgänge zwischen Systemen, die zeitkritische Kommunikationsdienste innerhalb des Data-Link Layer des OSI- oder Feldbus-Referenzmodells unterstützen und die die Fähigkeit des Durchverbindens in einem Umfeld der Kommunikation offener Systeme erfordern.

Profile stellen eine einfache multiattributive Einrichtung zum Zusammenfassen des Vermögens einer Implementierung bereit und somit deren Anwendbarkeit auf verschiedene zeitkritische Kommunikationsanforderungen.

1.5 Konformität

Dieses Dokument legt außerdem Konformitätsanforderungen für Systeme fest, die diese Verfahren umsetzen. Dieses Dokument enthält keine Prüfungen zum Darlegen der Erfüllung solcher Anforderungen.

3 Begriffe, Symbole, Abkürzungen und Vereinbarungen

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe, Symbole, Abkürzungen und Vereinbarungen.

ISO und IEC stellen terminologische Datenbanken für die Verwendung in der Normung unter den folgenden Adressen bereit:

- IEC Electropedia: verfügbar unter <http://www.electropedia.org/>
- ISO Online Browsing Platform: verfügbar unter <http://www.iso.org/obp>

3.3 Allgemeine Begriffe

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe.

3.3.1

azyklische Übertragung

(en: acyclic transmission)

nicht periodischer Austausch von Telegrammen

3.3.2

C1-Master

(en: C1 master)

einer der Stationstypen, der die zyklische Übertragung initiiert und steuert

3.3.3

C1-Nachricht

(en: C1 message)

Nachrichtenkommunikation, bei der der C1-Master als Initiator zum Austausch von Nachrichten mit dem Slave oder C2-Master dient

3.3.4**C2-Master**

(en: C2 master)

einer der Stationstypen, der die Funktion hat, alle über das Netzwerk übertragene Prozessdaten zu überwachen, und der Nachrichtenkommunikation initiieren kann

3.3.5**C2-Nachricht**

(en: C2 message)

Nachrichtenkommunikation, bei der der C2-Master als Initiator zum Austausch von Nachrichten mit dem Slave oder dem C1-Master dient

3.3.6**zyklische Übertragung**

(en: cyclic transmission)

periodischer Austausch von Telegrammen

3.3.7**Daten**

(en: data)

allgemeine Bezeichnung für jegliche über einen Feldbus übertragene Informationen

3.3.8**Gerät**

(en: device)

an den Feldbus angeschlossene physische Instanz, die aus mindestens einem Kommunikationselement (dem Netzwerkelement) besteht und die ein Steuerungselement und/oder ein Abschlusselement (Wandler, Aktuator usw.) enthalten darf

3.3.9**ereignisgesteuerter Modus**

(en: event driven mode)

Übertragungsmodus für das Application-Layer-Protokoll des Kommunikationstyps 24, in welchem ein Vorgang von Befehl-Antwort-Austausch als Benutzeranforderung auftritt

3.3.10**Rahmen**

(en: frame)

Synonym für DLPDU

3.3.11**Initiator**

(en: initiator)

Station, die den Austausch von Prozessdaten oder Nachrichten einleitet

3.3.12**Schnittstelle**

(en: interface)

gemeinsam genutzte Grenze zwischen zwei funktionalen Einheiten, die durch funktionale Merkmale, Signalmuster oder andere Merkmale, soweit zutreffend, festgelegt ist

3.3.13**Eingangsdaten**

(en: input data)

Prozessdaten, die vom Slave gesendet und vom C1-Master empfangen werden

3.3.14

Nachricht

(en: message)

geordnete Folge von Oktetten für die Übermittlung von Informationen

Anmerkung 1 zum Begriff: Üblicherweise für die Übermittlung von Informationen zwischen Peers auf der Anwendungsschicht verwendet.

3.3.15

Überwachungs-Slave

(en: monitor slave)

Slave, der die Funktion hat, alle über das Netzwerk übermittelten Prozessdaten zu überwachen

3.3.16

Netzwerk

(en: network)

Menge von Knoten, die über ein bestimmtes Kommunikationsmedium miteinander verbunden sind, einschließlich jeglicher zwischengeschalteter Repeater, Bridges, Router und Gateways unterer Schichten

3.3.17

Knoten

(en: node)

<Protokoll> einzelne DL-Instanz, wie sie auf einem lokalen Verbindungsweig existiert

3.3.18

Knoten

(en: node)

<Vernetzung, Netzwerk> Endpunkt eines Verbindungsweigs in einem Netzwerk oder Punkt, an dem zwei oder mehrere Verbindungsweige aufeinandertreffen

3.3.19

Ausgangsdaten

(en: output data)

Prozessdaten, die vom C1-Master gesendet und von den Slaves empfangen werden

3.3.20

Protokoll

(en: protocol)

Vereinbarung über die Datenformate, Zeitabfolgen und die Fehlerkorrektur im Datenaustausch von Kommunikationssystemen

3.3.21

Echtzeit-Kommunikation

(en: real-time communication)

Übertragung von Daten in Echtzeit

3.3.22

empfangender DLS-Benutzer

(en: receiving DLS-user)

Benutzer der DL-Dienste, der als Empfänger von DL-Benutzerdaten agiert

Anmerkung 1 zum Begriff: Ein Benutzer der DL-Dienste darf gleichzeitig sendender und empfangender DLS-Benutzer sein.

3.3.23

Antwortender

(en: responder)

Station, die mit Prozessdaten oder Nachrichten reagiert, nachdem sie vom Initiator initiiert wurde

3.3.24

Daten senden mit Quittierung

(en: send data with acknowledge)

Datentransferdienst mit Quittierung des Empfangs von der entsprechenden DLE

3.3.25

Daten senden ohne Quittierung

(en: send data without acknowledge)

Datentransferdienst ohne Quittierung des Empfangs von der entsprechenden DLE

3.3.26

Slave

(en: slave)

einer der Stationstypen, der nur auf das Medium zugreift, nachdem er vom C1-Master oder C2-Master initiiert wurde

3.3.27

sendender DLS-Benutzer

(en: sending DLS-user)

Benutzer der DL-Dienste, der als Quelle von DL-Benutzerdaten agiert

3.3.28

Station

(en: station)

Knoten (en: node)

3.3.29

Topologie

(en: topology)

physische Netzwerkarchitektur in Bezug auf die Verbindung zwischen den Stationen des Kommunikationssystems

3.3.30

Übertragungszyklus

(en: transmission cycle)

festgelegter Zeitraum zyklischer Übertragung

3.3.31

Zeitfenster

(en: time slot)

reservierter Zeitraum, sodass der Initiator und der Beantworter jeweils einen Rahmen austauschen dürfen

– Leerseite –

English Version

Industrial communication networks - Fieldbus specifications -
Part 4-24: Data-link layer protocol specification -
Type 24 elements
(IEC 61158-4-24:2019)

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 61158-4-24:2019)

Industrielle Kommunikationsnetze - Feldbusse -
Teil 4-24: Protokollspezifikation des Data-Link Layer
(Sicherheitsschicht) - Typ 24-Elemente
(IEC 61158-4-24:2019)

This European Standard was approved by CENELEC on 2019-05-23. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 65C/946/FDIS, future edition 2 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 61158-4-24:2019.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by (dop) 2020-02-23
publication of an identical national standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2022-05-23
document have to be withdrawn

This document supersedes EN 61158-4-24:2014.

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

Endorsement notice

The text of the International Standard IEC 61158-4-24:2019 was approved by CENELEC as a European Standard without any modification.

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

IEC 61158-1	NOTE	Harmonized as EN 61158-1.
IEC 61784-1	NOTE	Harmonized as EN 61784-1.
IEC 61784-2	NOTE	Harmonized as EN 61784-2.

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.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61158-2	-	Industrial communication networks - Fieldbus specifications - Part 2: Physical layer specification and service definition	EN 61158-2	-
IEC 61158-3-24	2014	Industrial communication networks - Fieldbus specifications - Part 3-24: Data-link layer service definition - Type 24 elements	EN 61158-3-24	2014
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 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		-
ISO/IEC/IEEE 8802-3:2017		Standard for Ethernet	-	-

CONTENTS

European foreword	2
Annex ZA (normative) Normative references to international publications with their corresponding European publications	3
INTRODUCTION	9
1 Scope.....	11
1.1 General	11
1.2 Specifications.....	11
1.3 Procedures.....	11
1.4 Applicability	12
1.5 Conformance	12
2 Normative references	12
3 Terms, definitions, symbols, abbreviations and conventions	12
3.1 Reference model terms and definitions	13
3.2 Service convention terms and definitions	14
3.3 Common terms and definitions	14
3.4 Symbols and abbreviations.....	17
3.5 Additional Type 24 symbols and abbreviations	18
3.6 Common Conventions	18
3.7 Additional Type 24 conventions.....	19
3.7.1 Primitive conventions.....	19
3.7.2 State machine conventions	19
4 Overview of DL-protocol	20
4.1 Characteristic feature of the DL-protocol	20
4.2 DL layer component.....	21
4.2.1 Cyclic transmission control (CTC)	22
4.2.2 Send Receive Control (SRC).....	22
4.2.3 DL-management.....	22
4.3 Timing sequence.....	22
4.3.1 Overview	22
4.3.2 Cyclic transmission mode	22
4.3.3 Acyclic transmission mode	30
4.4 Service assumed from the PhL.....	31
4.4.1 General requirement.....	31
4.4.2 DL_Symbols	31
4.4.3 Assumed primitives of the PhS.....	31
4.5 Local parameters, variables, counters, timers.....	31
4.5.1 Overview	31
4.5.2 Variables, parameters, counters and timers to support DLE function.....	32
5 DLPDU structure.....	36
5.1 Overview	36
5.1.1 Transfer syntax for bit sequences	36
5.1.2 Data type encodings	37
5.1.3 Frame format	37
5.2 Basic format DLPDU structure.....	37
5.2.1 General	37

5.2.2	Synchronous frame	41
5.2.3	Output data or Input data frame	41
5.2.4	Delay measurement start frame	42
5.2.5	Delay measurement frame	42
5.2.6	Message token frame	43
5.2.7	Status frame	43
5.2.8	Cycle Information frame	44
5.2.9	Message frame.....	45
5.3	Short format DLPDU structure.....	46
5.3.1	General.....	46
5.3.2	Synchronous frame	48
5.3.3	Output data or Input data frame	49
5.3.4	Message frame.....	49
6	DLE element procedure	50
6.1	Overview.....	50
6.2	Cyclic transmission control sublayer	50
6.2.1	General.....	50
6.2.2	DLS-user interface	50
6.2.3	Protocol machines in CTC.....	51
6.2.4	CTC-DLM interface	102
6.3	Send Receive Control.....	103
6.3.1	General.....	103
6.3.2	SRC-CTC interface	104
6.3.3	Detailed specification of SRC.....	105
6.3.4	SRC-DLM interface	109
7	DL-management layer (DLM).....	110
7.1	Overview.....	110
7.2	Primitive definitions.....	110
7.2.1	Primitives exchanged between DLMS-user and DLM	110
7.2.2	Parameters used with DLM primitives.....	111
7.3	DLM protocol machine.....	111
7.3.1	C1 master	111
7.3.2	Slave and C2 master.....	116
7.4	Functions	120
	Bibliography	123
	Figure 1 – Data-link layer component	22
	Figure 2 – Timing chart of fixed-width time slot type cyclic communication.....	23
	Figure 3 – Timing chart of configurable time slot type cyclic communication	25
	Figure 4 – Schematic diagram of cyclic event occurrence.....	27
	Figure 5 – Timing relationship between cyclic transmission and data processing.....	30
	Figure 6 – Timing chart example of acyclic communication.....	30
	Figure 7 – Basic format DLPDU structure	38
	Figure 8 – Short format DLPDU structure	46
	Figure 9 – The state diagram of the C1 master for fixed-width time slot	52
	Figure 10 – The state diagram of the C2 master for fixed-width time slot	59

Figure 11 – The state diagram of the slave for fixed-width time slot	63
Figure 12 – The state diagram of the C1 master for configurable time slot	66
Figure 13 – The state diagram of the C2 master for configurable time slot	75
Figure 14 – The state diagram of slave for configurable time slot.....	78
Figure 15 – The state diagram of message initiator for basic format	83
Figure 16 – The state diagram of message responder for basic format.....	87
Figure 17 – The state diagram of message initiator for short format.....	91
Figure 18 – The state diagram of message responder for short format.....	95
Figure 19 – The state diagram of the acyclic transmission protocol machine.....	101
Figure 20 – Internal architecture of one-port SRC.....	105
Figure 21 – Internal architecture of multi-port SRC	105
Figure 22 – Internal architecture of serializer	106
Figure 23 – Internal architecture of deserializer	107
Figure 24 – State diagram of the C1 master DLM.....	112
Figure 25 – State diagram of the Slave and the C2 master DLM.....	117
Table 1 – State transition descriptions	19
Table 2 – Description of state machine elements.....	20
Table 3 – Conventions used in state machines	20
Table 4 – Characteristic features of the fieldbus data-link protocol.....	21
Table 5 – List of the values of the variable Cyc_sel	32
Table 6 – List of the values of the variable Tunit.....	33
Table 7 – List of the values of the variable PDUType	34
Table 8 – List of the values of the variable SlotType.....	35
Table 9 – Transfer syntax for bit sequences	37
Table 10 – Bit order	37
Table 11 – Destination and Source address format	38
Table 12 – Station address.....	38
Table 13 – Extended address.....	39
Table 14 – Message control field format (Information transfer format)	39
Table 15 – Message control field format (Supervisory format).....	39
Table 16 – The list of Supervisory function bits.....	40
Table 17 – Frame type and data length format	40
Table 18 – The list of Frame type	40
Table 19 – Data format of the Synchronous frame.....	41
Table 20 – The field list of the Synchronous frame	41
Table 21 – Data format of the Output data or the Input data frame	41
Table 22 – The field list of the Output data or the Input data frame	42
Table 23 – Data format of Delay measurement start frame	42
Table 24 – The field list of Delay measurement start frame.....	42
Table 25 – Data format of Delay measurement frame	43
Table 26 – The field list of Delay measurement frame	43

Table 27 – Data format of Status frame	43
Table 28 – The field list of Status frame	44
Table 29 – The list of the DLE status	44
Table 30 – The list of Repeater status	44
Table 31 – Data format of Delay measurement frame	45
Table 32 – The field list of Cycle Information frame	45
Table 33 – Data format of Message frame	45
Table 34 – The field list of Message frame	46
Table 35 – Range of Station address field	47
Table 36 – Control field format (I/O data exchange format)	47
Table 37 – Control field format (Message format)	47
Table 38 – The field list of Message format	48
Table 39 – Data format of the Synchronous frame	48
Table 40 – The field list of the Synchronous frame	48
Table 41 – Data format of the Output data frame	49
Table 42 – The field list of the Output data frame	49
Table 43 – Data format of the Input data frame	49
Table 44 – The field list of the Input data frame	49
Table 45 – Primitives and parameters for the DLS-user interface issued by the DLS-user	50
Table 46 – Primitives and parameters for the DLS-user interface issued by the CTC	50
Table 47 – The state table of the C1 master for fixed-width time slot	53
Table 48 – The state table of the C2 master for fixed-width time slot	60
Table 49 – The state table of the slave for fixed-width time slot	64
Table 50 – The state table of the C1 master for configurable time slot	67
Table 51 – The state table of the C2 master for configurable time slot	76
Table 52 – The state table of slave for configurable time slot	79
Table 53 – The list of functions used by cyclic transmission machine	80
Table 54 – The state table of message initiator for basic format	83
Table 55 – The state table of message responder for basic format	87
Table 56 – The state table of message initiator for short format	91
Table 57 – The state table of message responder for short format	96
Table 58 – List of functions used by the message segmentation machine	100
Table 59 – The state table of the acyclic transmission protocol machine	102
Table 60 – The list of functions used acyclic transmission protocol machine	102
Table 61 – Primitives and parameters exchanged between CTC and DLM	103
Table 62 – Error event primitive and parameters	103
Table 63 – primitives and parameters for SRC-CTC interface	104
Table 64 – Send frame primitive and parameters	104
Table 65 – Receive frame primitives and parameters	105
Table 66 – Primitives and parameters exchanged between SRC and DLM	109
Table 67 – Get value primitive and parameters	110
Table 68 – Error event primitive and parameters	110

Table 69 – The list of primitives and parameters (DLMS-user source)..... 111

Table 70 – The list of primitives and parameters (DLM source)..... 111

Table 71 – State table of the C1 Master DLM 113

Table 72 – State table of the Slave and the C2 master DLM 118

Table 73 – The list of the functions used by DLM protocol machine..... 121

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:

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

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

NOTE Use of some of the associated protocol types is restricted by their intellectual-property-right holders. In all cases, the commitment to limited release of intellectual-property-rights made by the holders of those rights permits a particular data-link layer protocol type to be used with physical layer and application layer protocols in Type combinations as specified explicitly in the profile series. Use of the various protocol types in other combinations may require permission from their respective intellectual-property-right holders.

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US 8223804 JP 4760978 CN 200880002225.3 DE 602008046644.2	[YE]	COMMUNICATION DEVICE, SYNCHRONIZED SYSTEM, AND SYNCHRONIZED COMMUNICATION METHOD
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US 7769935 JP 4683346 US 8046512 DE 602007041530.6	[YE]	MASTER SLAVE COMMUNICATION SYSTEM AND MASTER SLAVE COMMUNICATION METHOD
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JP 4356698	[YE]	COMMUNICATION DEVICE, SYNCHRONIZED COMMUNICATION SYSTEM, AND SYNCHRONIZED COMMUNICATION METHOD
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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:

- a) in a synchronously-starting cyclic manner, according to a pre-established schedule, or
- b) 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 document specifies

- a) procedures for the timely transfer of data and control information from one data-link user entity to a peer user entity, and among the data-link entities forming the distributed datalink service provider;
- b) 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;
- c) 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;
- d) procedures for giving cyclic and acyclic communication opportunities for time-critical data transmission with prioritized access;
- e) 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;
- f) 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

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

1.4 Applicability

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

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

1.5 Conformance

This 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 IEC 61784-1 and IEC 61784-2 are maintained simultaneously. Cross-references to these documents within the text therefore refer to the editions as dated in this list of normative references.

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

IEC 61158-3-24:2014, *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 8802-3:2017, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements –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*

3 Terms, definitions, symbols, abbreviations and conventions

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

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

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

3.1 Reference model terms and definitions

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

3.1.1	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)	
	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 station type 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 station type that has the function of monitoring all process data transmitted through the network and may 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

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 may have 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

station 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

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 may be concurrently both a sending and receiving DLS-user.

3.3.23

responder

station 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 station type that accesses the medium only after it has been initiated by C1 master 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 stations 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 may exchange one frame respectively

3.4 Symbols and abbreviations

3.4.1	DA	Destination address
3.4.2	DL-	Data-link layer (as a prefix)
3.4.3	DLE	DL-entity (the local active instance of the data-link layer)
3.4.4	DLL	DL-layer
3.4.5	DLM	DL-management
3.4.6	DLME	DL-management entity (the local active instance of DL-management)
3.4.7	DLMS	DL-management service
3.4.8	DLPDU	DL-protocol-data-unit
3.4.9	DLS	DL-service
3.4.10	DLSAP	DL-service-access-point
3.4.11	DLSDU	DL-service-data-unit
3.4.12	FIFO	First-in first-out (queuing method)
3.4.13	ID	Identifier
3.4.14	OSI	Open systems interconnection
3.4.15	PDU	Protocol data unit
3.4.16	Ph-	Physical layer (as a prefix)
3.4.17	PhE	Ph-entity (the local active instance of the physical layer)
3.4.18	PhL	Ph-layer
3.4.19	PHY	Physical layer device (specified in ISO/IEC/IEEE 8802-3)
3.4.20	QoS	Quality of service
3.4.21	RT	Real-time
3.4.22	SAP	Service access point
3.4.23	SDU	Service data unit

3.5 Additional Type 24 symbols and abbreviations

3.5.1	ACK	Acknowledge
3.5.2	C1MSG	C1 message
3.5.3	C2MSG	C2 message
3.5.4	I/O	Input and/or output
3.5.5	MSG	Message
3.5.6	Rx	Receive
3.5.7	SDA	Send data with acknowledge
3.5.8	SDN	Send data without acknowledge
3.5.9	SM	State machine
3.5.10	Tcycle	Transmission cycle
3.5.11	Tslot	Time slot
3.5.12	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.

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 may or may not be provided 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.

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 is shown in Table 2.

Table 2 – Description of state machine elements

Description element	Meaning
No	Number of the transition.
Current state, 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.

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)) -C2 master (active station with restricted bus access control, max.1 (optional)) -Slave (passive stations without bus access control, max.62)
Station addressing	1 to 255 (255 = global address for broad-cast messages), 8 bit-width address extension for integrated device
Transmission cycle	31,25 us to 64 ms
DLSDU size	8 to 64 octets
Transmission characteristic	-Cyclic data exchange and cyclic event, synchronized with accurate cycle time (jitter below 1 us) -Max 62 times (n times/1 station) retry within cycle time -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 31,25 [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, one is “fixed-width time slot type” whose time slot is same width for all stations and the other is “configurable time slot type” whose time slot can be defined for each station. 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 may 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.

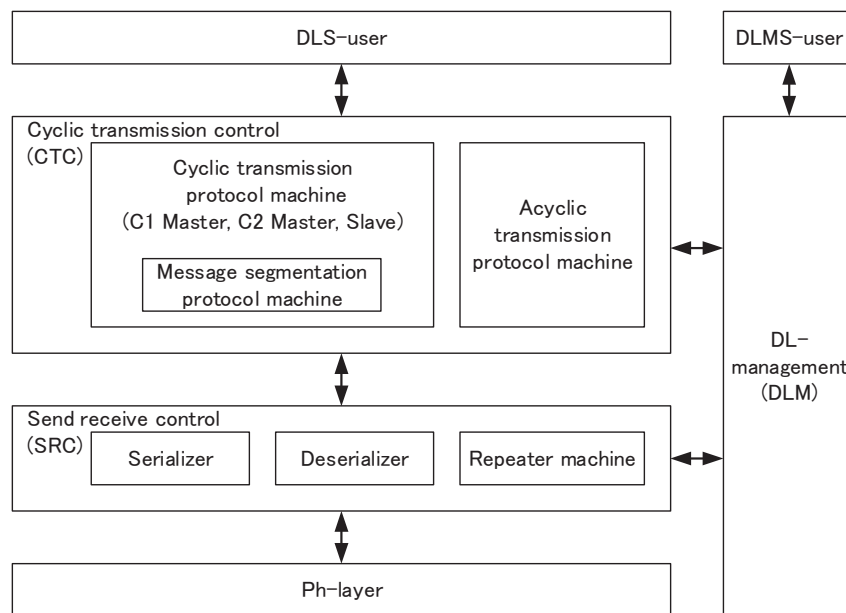


Figure 1 – Data-link layer component

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 cyclic transmission has two types, one is “fixed-width time slot type” whose time slot is same width for all stations and the other is “configurable time slot type” whose time slot can be defined for each station.

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, the width of all time slots is the same.

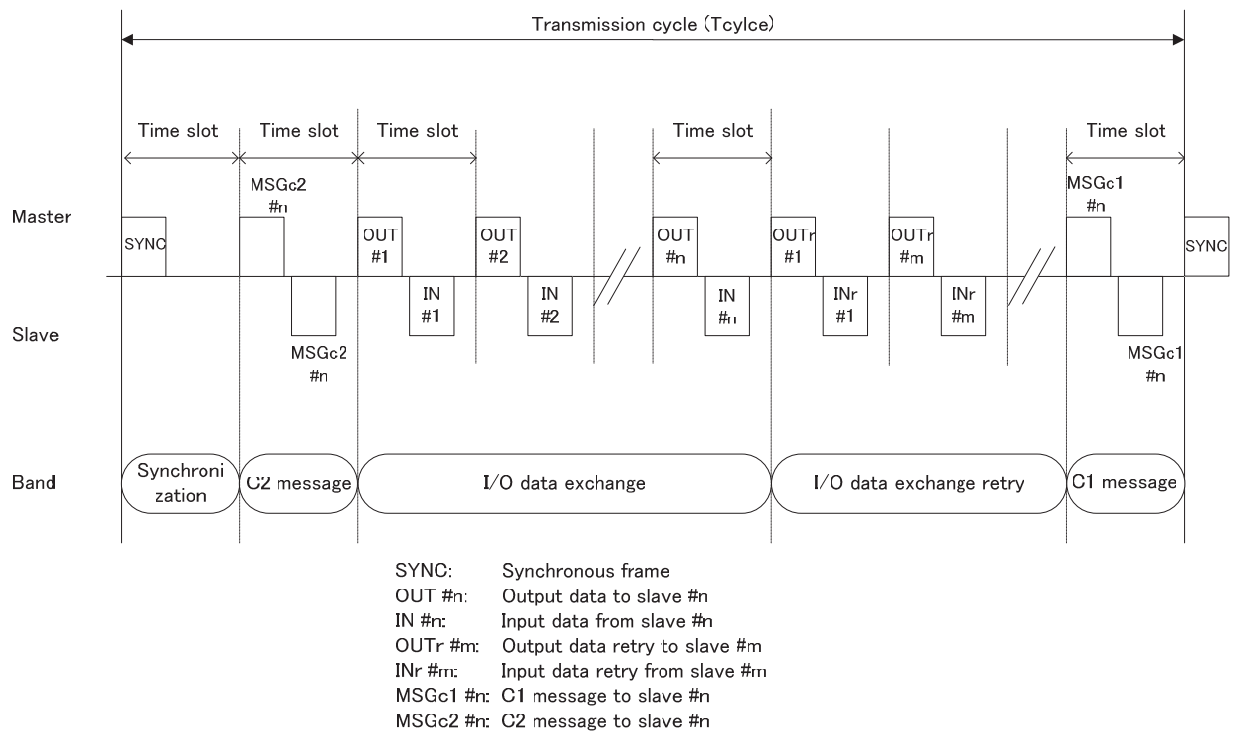


Figure 2 – Timing chart of fixed-width time slot type cyclic communication

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 may be allocated to this band, and request and response may be 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 where the C1 master retries the I/O data exchanges according to the retry list. The C1 master may 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 starts.

The C1 master may 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 may be configured in this band. This band may be 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 4.3.2.2.

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

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 may be 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:

$$\begin{aligned} T_{slot} &= \max(T_{tr_c}(n) + T_{dly}(n) + T_{gap} + T_{tr_r}(n) + T_{dly}(n) + T_{gap}) \\ &= 2 \times \max(T_{tr_c}(n) + T_{dly}(n) + T_{gap}) \end{aligned} \quad (5)$$

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.

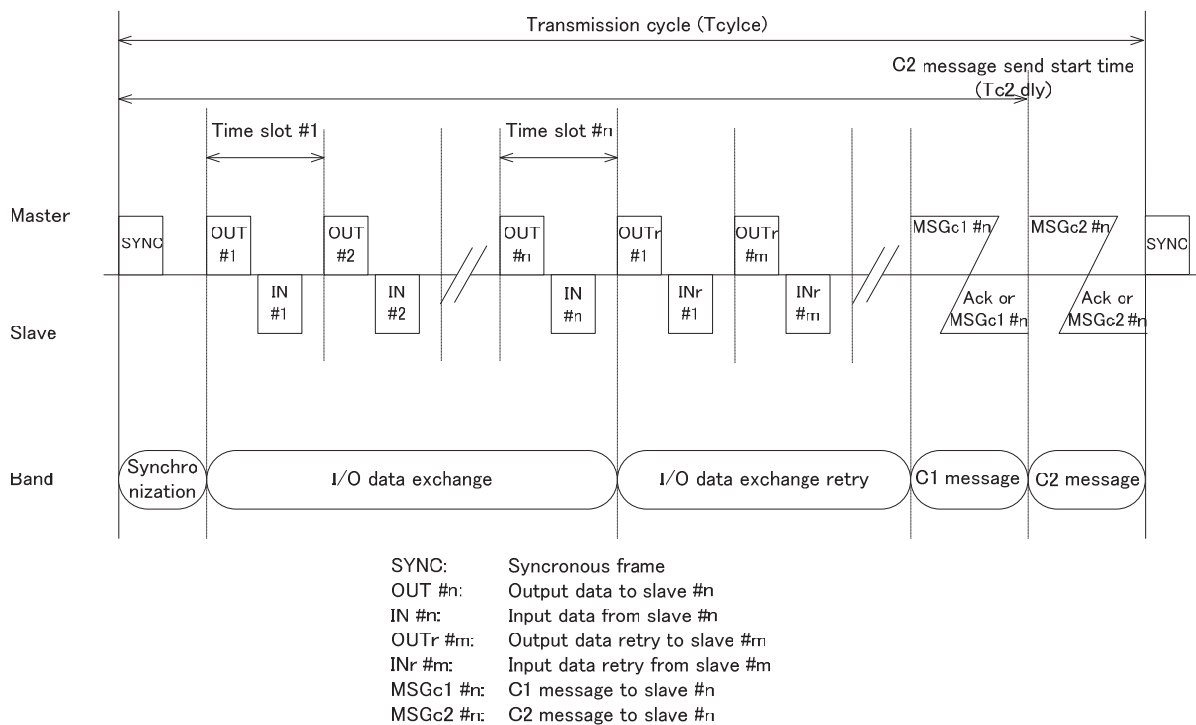


Figure 3 – Timing chart of configurable time slot type cyclic communication

4.3.2.2.2 Detailed description of communication phase

4.3.2.2.2.1 Synchronization

See 4.3.2.1.2.1.

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 may 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 may 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 may 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 may be assigned to this band.

The C1 master may execute the C1 message transmission within the residual time. The C1 master may 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 may be 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 may execute the C2 message transmission within the allocated bandwidth. The C2 master may repeat the C2 message transmission that consists of one pair of request and 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 may be 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 may 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 the 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 the all slaves at the cycle event timing, the system can operate synchronously.

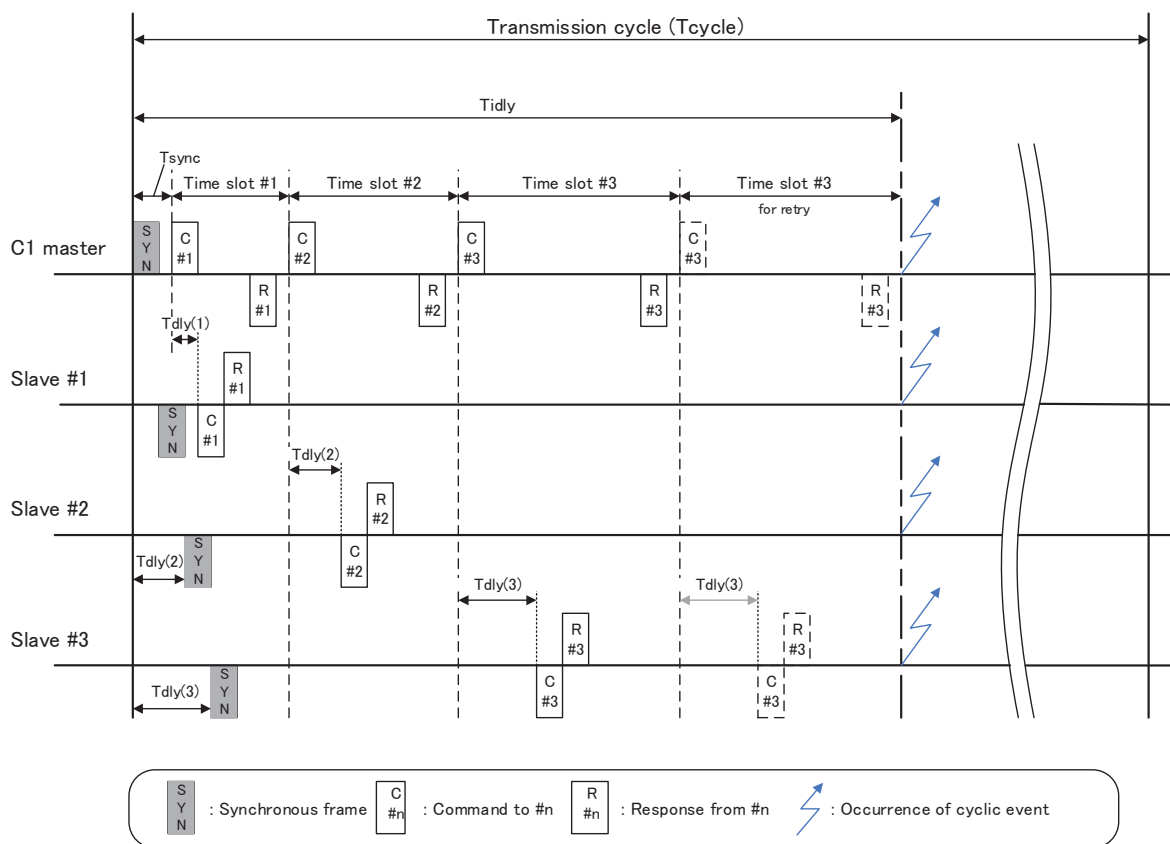


Figure 4 – Schematic diagram of cyclic event occurrence

The transmission cycle of the variable time slot type T_{cycle} is calculated as an aggregation of the band described in 4.3.2.3.2, 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;

Tretry 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 may be configured to be shared. When they are shared, the formula becomes:

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

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.

a) 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:

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

b) 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:

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

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

c) I/O data exchange retry band

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

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

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

d) C1 message band

The C1 message band T_{c1msg} is calculated as follows: where $T_{tr_c1c}(m1)$ is the request transmission time from the primary station (C1 master) to the secondary station $m1$ ($m1$ is the station number of slaves or the C2 master that becomes the secondary station), $T_{tr_c1r}(m1)$ 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, N_{c1msg} is the number of the C1 messages:

$$T_{C1msg} = N_{c1msg} \times \{T_{tr_c1c}(m_1) + T_{dly}(m_1) + T_{gap} + T_{tr_c1r}(m_1) + T_{dly}(m_1) + T_{gap}\} \quad (12)$$

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

e) 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:

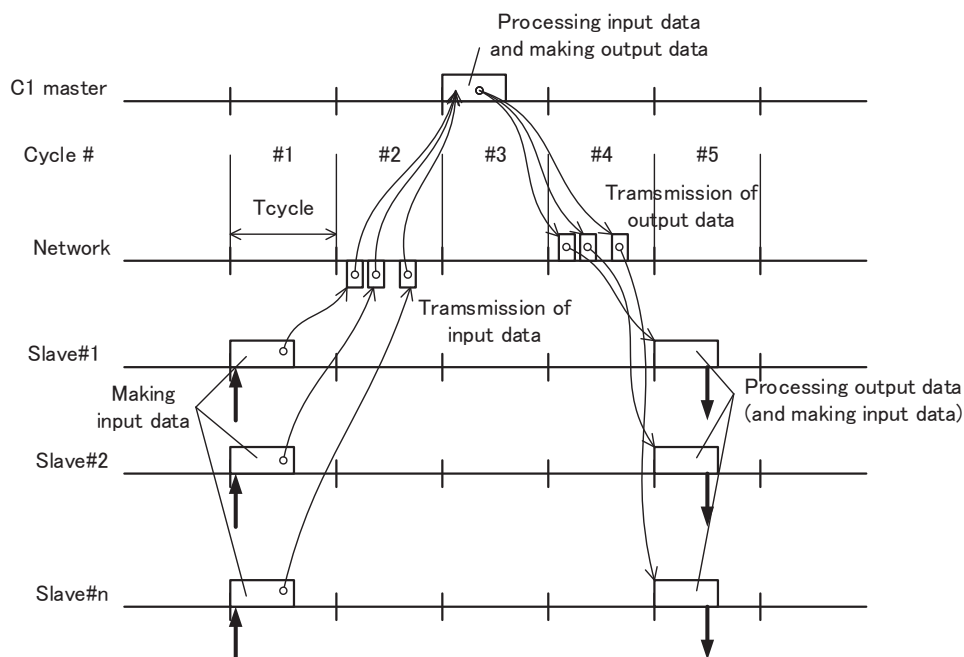
$$T_{c2msg} = N_{c2msg} \times \{T_{tr_c2c}(m_2) + T_{dly}(m_2) + T_{gap} + T_{tr_c2r}(m_2) + T_{dly}(m_2) + T_{gap}\} \quad (13)$$

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

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 the 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.



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

4.3.3 Acyclic transmission mode

The acyclic transmission may 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 may 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.

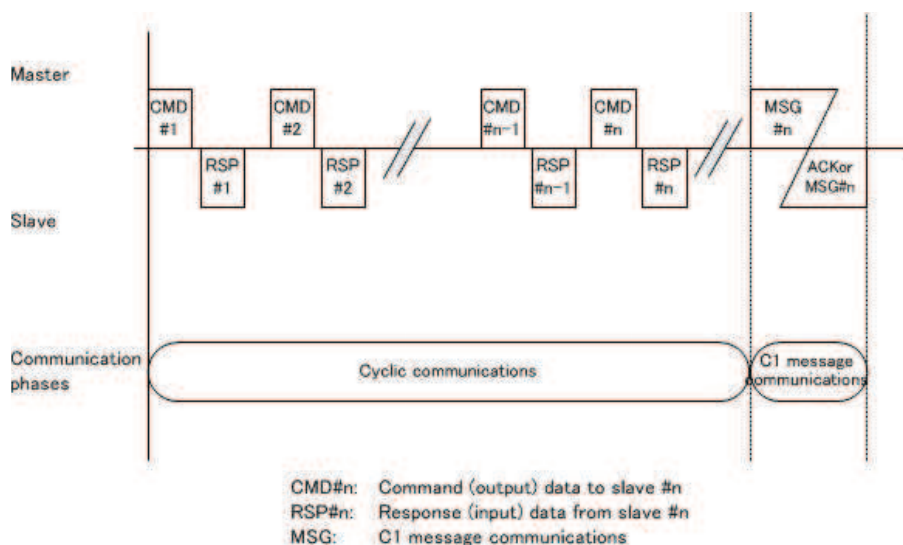


Figure 6 – Timing chart example of acyclic communication