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PAS 62410

First edition
2005-08

Real-time Ethernet SERCOS III



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Real-time Ethernet SERCOS III

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The Interest Group SERCOS interface (IGS) has the patent applications listed below:

German Publication Number DE 102 37 097 A1.

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IEC-PAS 62410 has been processed by subcommittee 65C: Digital communications, of IEC technical committee 65: Industrial-process measurement and control.

The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document

Draft PAS	Report on voting
65C/358/NP	65C/374/RVN

Following publication of this PAS, the technical committee or subcommittee concerned will transform it into an International Standard.

It is intended that the content of this PAS will be incorporated in the future new editions of the various parts of the IEC 61158 series and IEC 61784 series according to the structure of these series.

This PAS shall remain valid for an initial maximum period of three years starting from 2005-08. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

INTRODUCTION

This PAS relates to the integration of SERCOS III fieldbus specification in future editions of IEC 61158 and IEC 61784 series.

It shows in various clauses what updates are required in each of these individual standards. All definitions, abbreviations and symbols that relate to SERCOS III appear together in Section F, which belongs to the updates of IEC 61784-2, as a temporary fix.

NOTE 1 Some sections of this PAS still refer to IEC 61491. As it has been decided to split this standard into future IEC 61800 series, under consideration, (power drive systems) and IEC 61158/61784 series (communication) according to 65C/365/RQ, references to these new standards will be incorporated later on, in accordance with the relevant SC22G and SC65C working groups.

NOTE 2 For the reader who is unfamiliar with SERCOS interfaces, 17.3 of Section F can serve as a preface to the specific details which follow in later clauses.

NOTE 3 A temporary "Type S" has been allocated for SERCOS III.

The SERCOS/CPF16 standard structure is described in the table below.

IEC 61784-1 (new edition)	Communication profiles CP16/1 and CP16/2.	
	CP16/1 fits to the existing SERCOS specification IEC 61491:2002 (fibre optic media, 2 and 4 Mbit/s). IEC 61491 (new edition) shall not specify any communication and refer instead to CP16/1 in IEC 61784-1 after release of its new edition according to this structure proposal.	
	CP16/2 fits to the 2 nd SERCOS generation (fibre optic media, 2, 4, 8 and 16 Mbit/s), which is downwards compatible to IEC 61491:2002 (CP16/1) while specifying additional features.	
IEC 61784-2 (1 st edition)	Communication profiles CP16/3.	
	CP16/3 fits to the newest, real-time Ethernet SERCOS generation, which is application compatible to IEC 61491:2002 (CP16/1) and CP16/2 while specifying additional communication features.	Defined in the PAS.
IEC 61158-2 (new edition)	Physical layer specification for all CPF16 profiles (Type not yet known)	
	Type specifications for CP16/1 and CP16/2	
	Type specifications for CP16/3	Defined in the PAS
IEC 61158-3 (new edition)	Data Link layer service specification for all CPF16 profiles (Type not yet known)	
	Type specifications for CP16/1 and CP16/2	
	Type specifications for CP16/3	Defined in the PAS
IEC 61158-4 (new edition)	Data Link layer protocol specification for all CPF16 profiles (Type not yet known)	
	Type specifications for CP16/1 and CP16/2	
	Type specifications for CP16/3	Defined in the PAS

IEC 61158-5 (new edition)	Application Link layer service specification for all CPF16 profiles (Type not yet known)	
	Type specifications for CP16/1 and CP16/2	
	Type specifications for CP16/3	Defined in the PAS
IEC 61158-6 (new edition)	Application Link layer protocol specification for all CPF16 profiles (Type not yet known)	
	Type specifications for CP16/1 and CP16/2	
	Type specifications for CP16/3	Defined in the PAS

Section A – Update of IEC 61158-2

0 Introduction

0.5 Major Physical Layer variations specified in IEC 61158-2

0.5.1 Type S: optical media and twisted-pair wire

Type S specifies the following synchronous transmission:

- a) optical fibre medium, at 2, 4, 8 and 16 Mbit/s;
- b) twisted-pair wire medium, at 100 Mbit/s, according to ISO/IEC 8802-3 – 100Base-TX;
- c) optical fibre medium, at 100 Mbit/s, according to ISO/IEC 8802-3 – 100Base-FX

2 Normative references

IEC 61491:2002, *Electrical equipment of industrial machines – Serial data link for real-time communication between controls and drives*.

ISO/IEC 8802-3:2001, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and Physical Layer specifications*.

29 Type S: Medium Attachment Unit: Ethernet 100Base-TX and 100 Base-FX

29.1 Transfer medium part of physical layer

29.1.1 Basics

The physical layer of the SERCOS profile is according to ISO/IEC 8802-3. Therein the transmission mode and the physical layer are specified. The transmission rate is 100 Mbit/s.

29.1.2 Topology

29.1.2.1 General

A SERCOS network uses slaves with integrated repeaters which have a constant delay time (t_{rep} , input → output). The topology consists of point-to-point transmission lines and participants. The master and the slaves are part of the network and are its participants. The connection line between the participants is a shielded CAT5 (or better) cable.

Each participant has two communication ports (port 1 and port 2). Port 1 (P1) and port 2 (P2) are interchangeable (see slave 3 in Figure 1 and Figure 2 for an example).

The topology can be either a ring structure or a line structure. A ring has two logical channels (see Figure 1) and a line has only one logical channel (see Figure 2).

The difference between ring and line structure is that the ring has a built-in redundancy against transmission media errors (e.g. cable break) and is therefore preferred.

A control unit may have one or more master interfaces depending on configuration. Each master handles only one network on the physical layer.

Slave interfaces are used to connect the devices to the network. At the physical layer, a slave represents the connection of one or more devices to the network. Logically, one slave with several devices acts the same as several slaves with each one device. The slaves are connected to each other physically through the network. Communication takes place between the master and the slaves; cross communication between the slaves is also supported.

The physical arrangement of slaves in the network is independent from the predefined device address ADR for the slave, as well as from the sequence of the real-time data fields in the AT and MDT. See 33.3.2 “Device address ADR” in IEC 61158-4, as well as 16.2 “Data transfer in RT channel” in IEC 61158-5.

Any slave can recognize the topology at any time, since there is a distinction between primary and secondary telegrams. This is important when a slave is added to the communication at a later point in time (hot plug). When a slave receives telegrams with the same SERCOS type on both ports (MDT0-P or MDT0-S) it recognizes a line. When it receives a MDT0-P on one port and a MDT0-S on the other port, it recognizes a ring.

29.1.2.2 Ring structure

The ring structure consists of a primary and secondary channel. All slaves work in forwarding mode (see Figure 1). Redundancy against cable break is achieved through this ring. It is also possible to open the ring and insert/remove slaves during operation (hot plug).

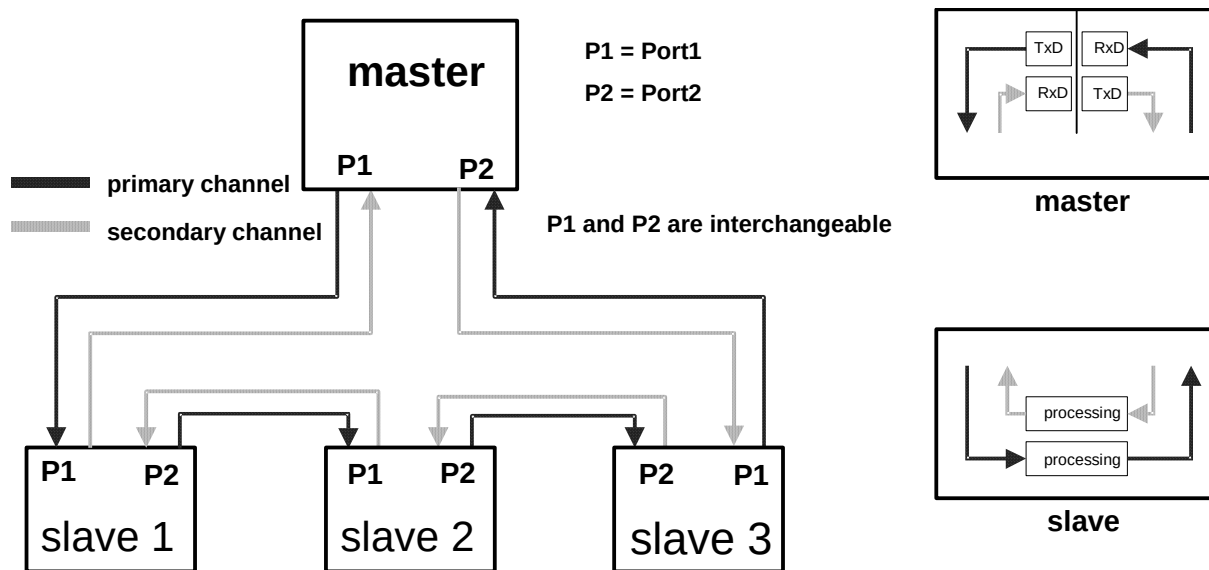


Figure 1 – Ring structure

29.1.2.3 Line structure

The line structure consists of either a primary or secondary channel. The last physical slave performs the loopback function. This is shown in Figure 2 with the loopback of slave 3. All other slaves work in forwarding mode. No redundancy against cable break is achieved. It is also possible to insert and remove slaves during operation (hot plug). This is restricted to the last physical slave. The ports which are not used for SERCOS communication (e.g., master port 2 and slave 3 port 1) can be used with IP communication. The master may communicate with slaves using two lines.

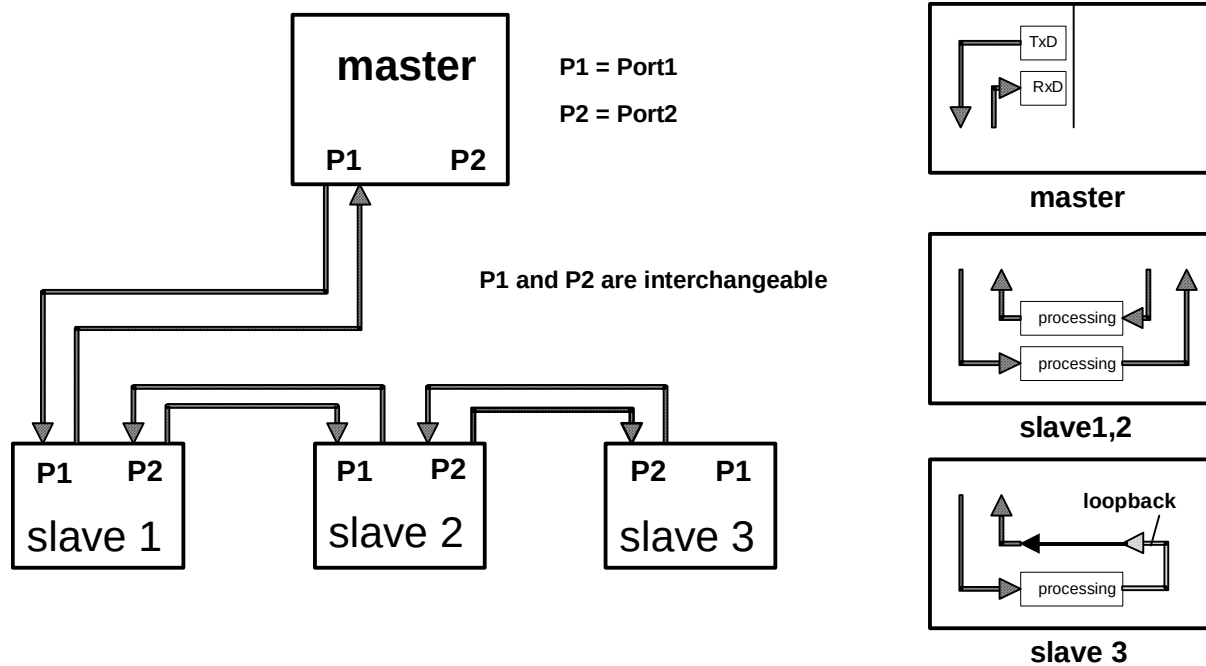


Figure 2 – Line structure

29.1.2.4 Transmission media

29.1.2.4.1 Transmission medium 100Base-TX

The characteristics of the 100Base-TX network are specified in ISO/IEC 8802-3. To ensure maximum noise immunity only shielded cables and connectors shall be used.

SERCOS devices shall use the MDI-X-ports with auto crossover function. The advantage is that standard cables as well as crossover cables (TxD / RxD) can be used.

29.1.2.4.2 Transmission medium 100Base-FX

The characteristics of the 100Base-FX network are specified in ISO/IEC 8802-3.

29.2 Communication mechanisms

29.2.1 General

Master and slave have the same hardware properties. Each port is assigned to a processing unit and a multiplexer (see Figure 3). The functions in the master and the slave depend on the topology and on the time slot within the communication cycle (RT channel or IP channel).

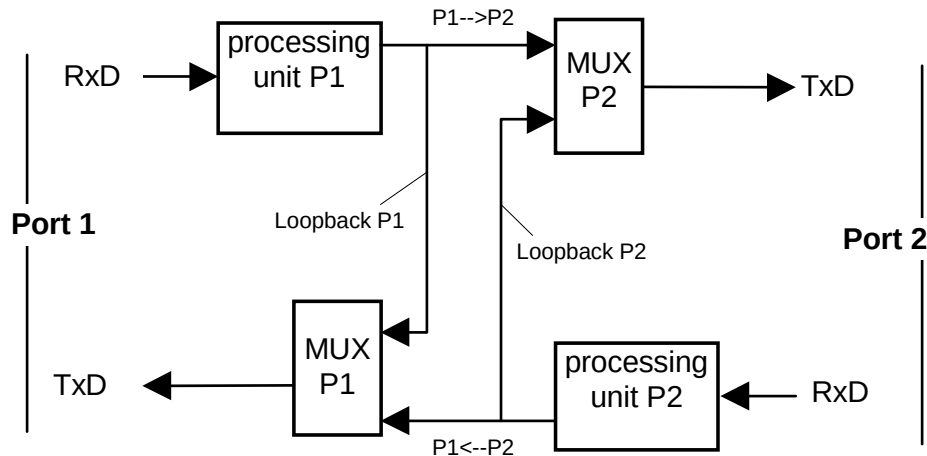


Figure 3 – Block diagram of master and slave

29.2.2 Forwarding

In the slave, the data from RxD (P1) shall be passed on with or without change to TxD (P2). The data from RxD (P2) shall be passed on with or without change to TxD (P1). See “Forwarding P1 → P2” and “Forwarding P2 → P1” in Figure 4). While the RT channel is active, the data shall be passed on, delayed by t_{REP} . While the IP channel is active, forwarding shall always be active and data shall be passed on, either at once or later in time, depending upon communication load.

In the master, forwarding shall always be switched off while the RT channel is active. While the IP channel is active, forwarding shall be:

- switched off if the master is connected to a single line configuration (only P1 or P2 is connected) or to an error-free ring configuration;
- activated if the master is connected to two independent lines or to a faulty ring configuration. Depending on the master’s functionality, the telegrams may be passed on either at once or later in time.

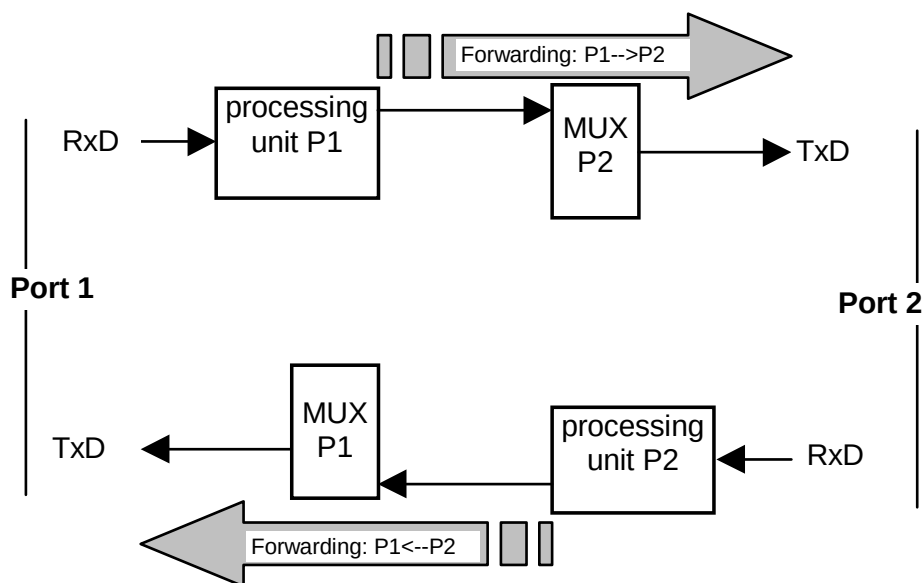


Figure 4 – Forwarding

29.2.3 Loopback

In the slave, the data from RxD (P1 or P2) shall be passed on with or without change to TxD (P1 and P2). Loopback may be activated either at P1 or P2 depending on the topology, but not at both ports simultaneously. The states are called “loopback P1”, respectively “loopback P2”. See Figure 5. While the IP channel is active, loopback shall never be active. While the RT channel is active, the slave shall activate loopback in the following (and only in those) cases:

- during CP0, as soon as an MDT0 has been received at a port (P1 or P2), but only as long as no MDT0 has been received at the other port;
- when the slave is the last physical one in the line topology;
- when a cable fault is detected.

The master shall have no loopback functionality.

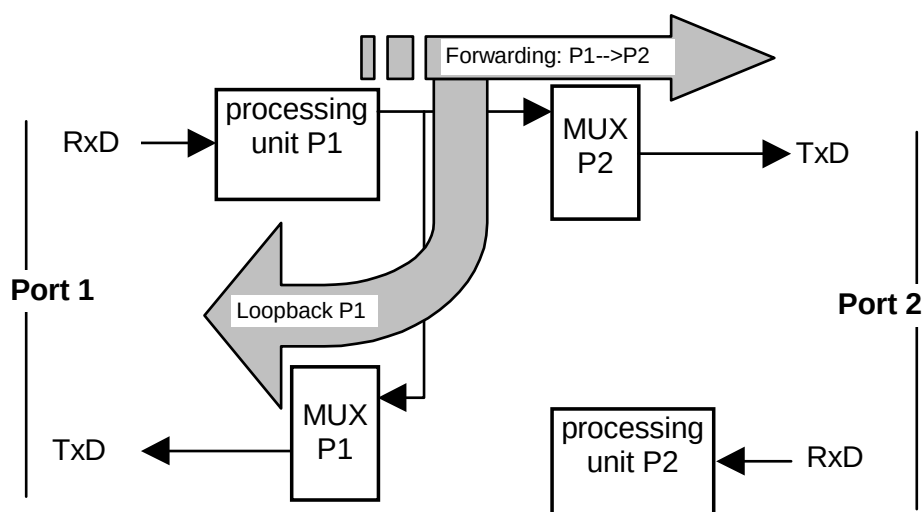


Figure 5 – Loopback

29.2.4 Device behaviour by addresses 0 and 255

Slaves with device addresses 0 and 255 shall also behave as described in 29.2.2 and 29.2.3. They shall also evaluate MDT0 in the same matter as the slaves with other addresses.

29.2.5 Redundancy of RT-Communication with ring topology

29.2.5.1 Ring topology without fault

Figure 6 shows an error free ring topology. The master shall send all telegrams with the same content on the P channel and on the S channel. Each slave shall receive both telegrams, work on the assigned data fields in P and S channel, and pass them on in their respective channels. Likewise, the master shall receive the telegrams from the slaves twice and process the data from the slave only once (either P or S channel).

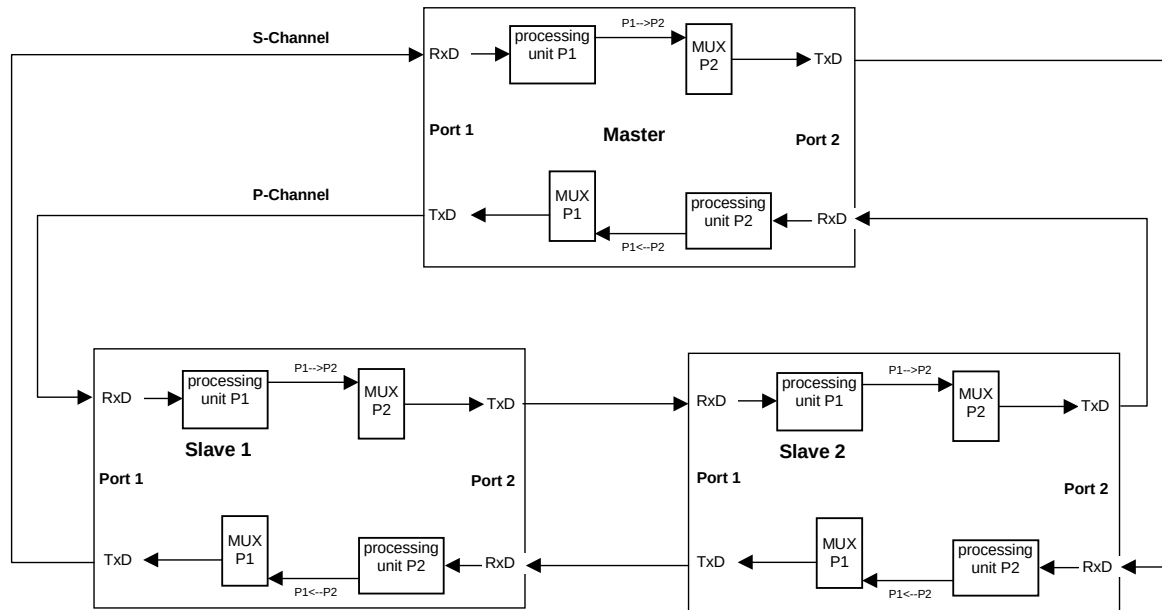


Figure 6 – Ring topology example with 2 slaves (example)

29.2.5.2 Cable faults between slaves

29.2.5.2.1 Case 1: Double channel interruption between two slaves

Figure 7 shows a first example of a faulty ring topology. Slave 1 shall detect an interruption at RxD of port 2 and close loopback at port 1. Slave 2 shall detect an interruption at RxD of port 1 and close loopback at port 2. The master shall receive the telegrams from slave 1 at port 1 only, and those from slave 2 at port 2 only.

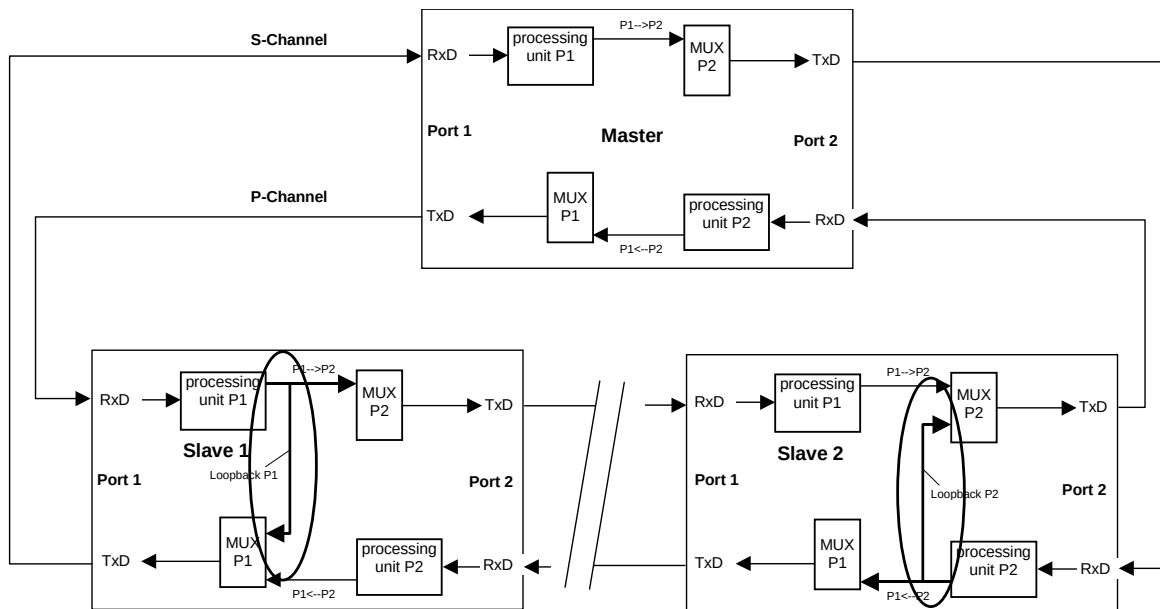


Figure 7 – Double channel interruption between two slaves (example)

29.2.5.2.2 Case 2: Single channel interruption between two slaves

Figure 8 shows another faulty ring topology example. Slave 1 shall detect an interruption at RxD of port 1 and close loopback at port 2. The master shall receive the telegrams from all slaves at port 1. At port 2, the master receives the telegrams from slave 2 in addition.

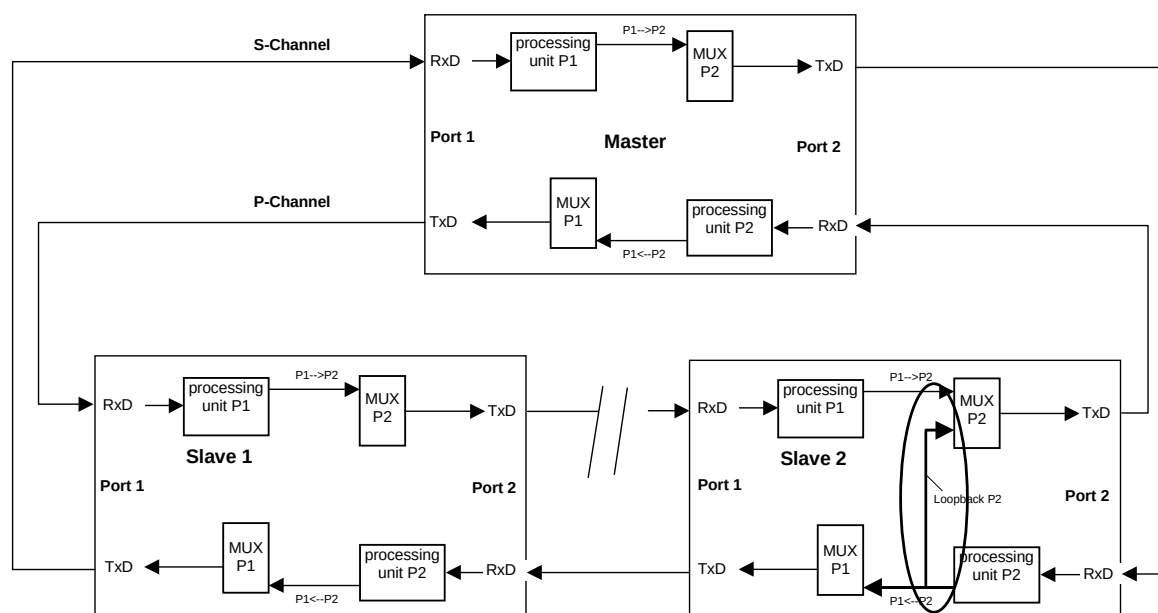


Figure 8 – Single channel interruption between two slaves (example)

29.2.5.3 Cable faults between master and slave

29.2.5.3.1 Case 1: Double channel interruption between master and slave

Figure 9 shows another faulty ring topology as an example. Slave 1 shall detect an interruption at RxD of port 1 and close loopback at port 2. The master shall detect an interruption at RxD of port 1. The master shall receive the telegrams from all slaves at port 2 only.

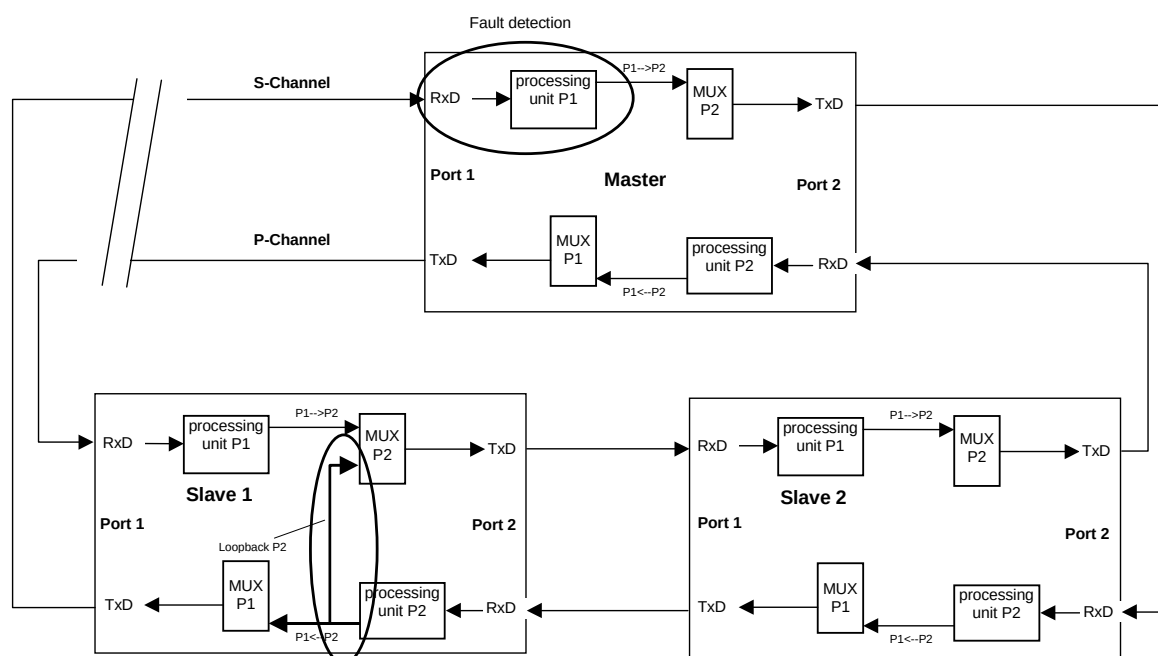


Figure 9 – Double channel interruption between the master and a slave (example)

29.2.5.3.2 Case 2: Single channel interruption between master output and slave

Figure 10 shows another faulty ring topology example. Slave 1 shall detect an interruption at RxD of port 1 and close loopback at port 2. The master shall receive the telegrams from all slaves twice.

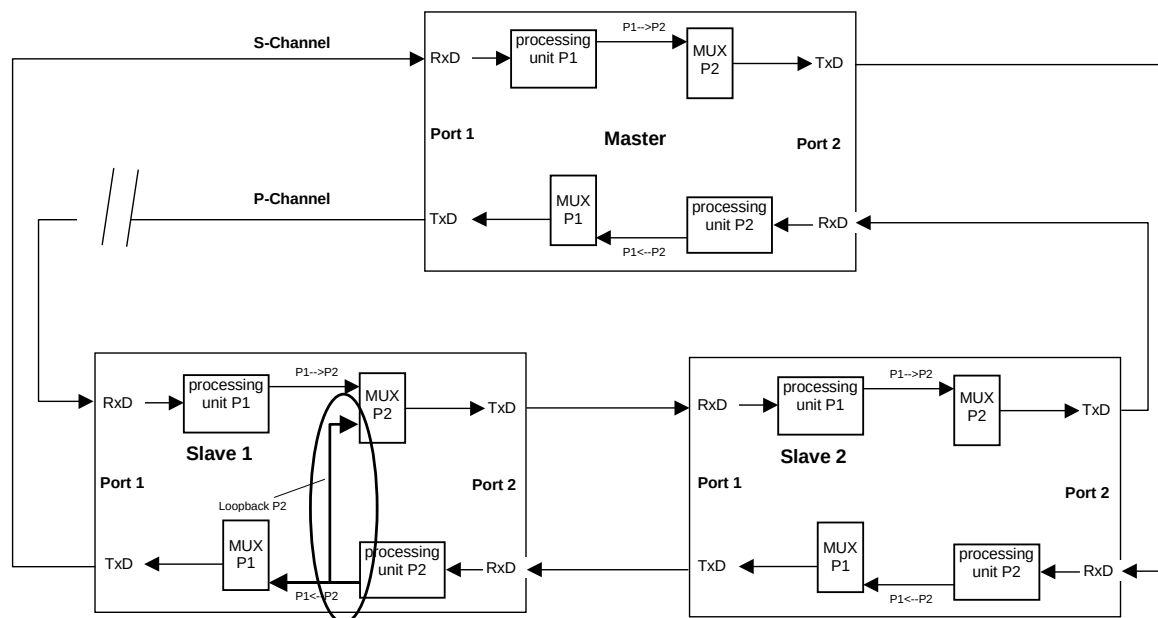


Figure 10 – Single channel interruption at master output (example)

29.2.5.3.3 Case 3: Single channel interruption between master input and slave

Figure 11 shows another faulty ring topology example. The master shall detect an interruption at RxD of port 1. The master shall receive the telegrams from all slaves at port 2 only.

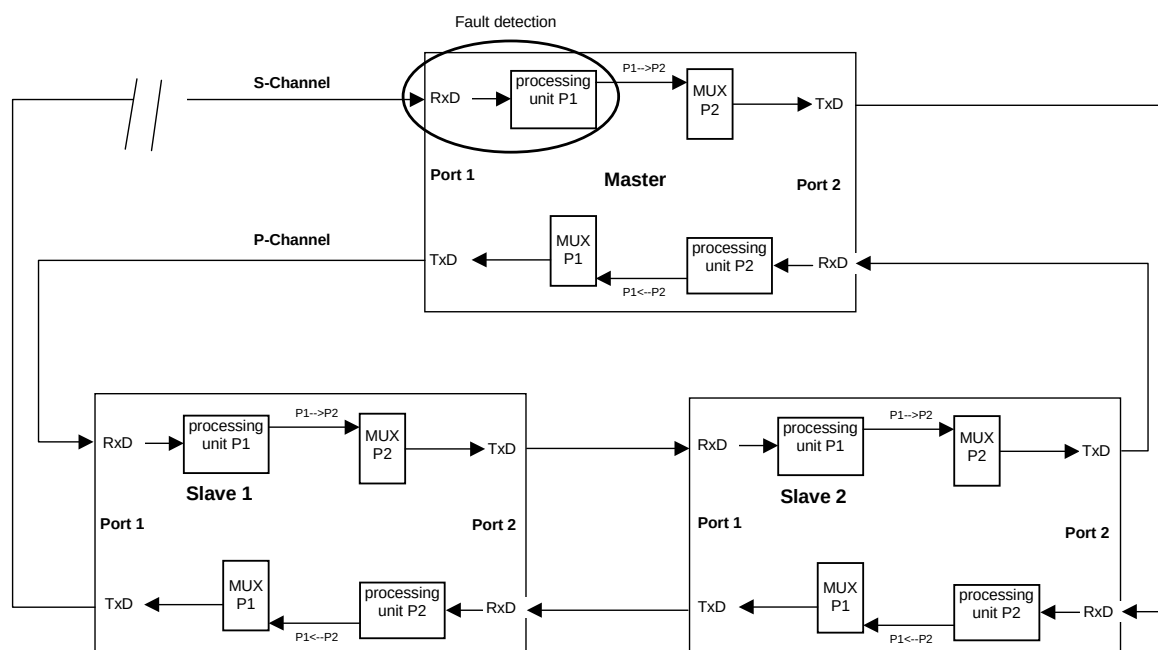


Figure 11 – Single channel interruption at master input (example)

29.2.6 IP communication mechanisms

29.2.6.1 Slaves within a line or a ring

Should a slave receive a telegram while IP channel is active and as it is transmitting an IP telegram, the currently transmitted IP telegram shall not be interrupted and the incoming telegram shall be stored.

Slaves shall always send their own IP telegrams on both ports (P1 and P2). The following conditions shall all be met before doing it:

- when it is forwarding a telegram, the slave shall wait that this telegram has been fully forwarded;
- the remaining IP channel duration is long enough to fully transmit its own IP telegram;
- its memory has enough free capacity for storing at least one new incoming IP telegram with maximum length.

Should a slave receive an MDT0 while it is sending an IP telegram, then it shall immediately interrupt this sending and forward the MDT0.

29.2.6.2 Slave in the last position within a line

Although the last slave in a line has its loopback active, it shall check for any incoming IP telegram on its other port. It shall forward IP telegrams when its IP channel is active, provided that the remaining duration of this IP channel is long enough to fully transmit this IP telegram. Otherwise, or if the IP channel is not active, the last slave shall store all incoming IP telegrams. It shall forward one or several of them as soon as IP channel is active again, provided that the remaining duration of this new IP channel is long enough.

Section B – Update of IEC 61158-3

1 Scope and object

1.1 Overview

Type S — A DL-service which provides a superset of those services expected of OSI Data Link Protocols as specified in ISO/IEC 8886.

2 Normative references

IEC 61491:2002, Electrical equipment of industrial machines - Serial data link for real-time communication between controls and drives.

ISO/IEC 8802-3:2001, Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and Physical Layer specifications.

21 Type S: Data Link concepts, services and management

21.1 Data transfer and data link layer

21.1.1 General

In this subclause, the telegram structure (frame structure) is described. Telegrams are according to the Ethernet standard ISO/IEC 8802-3.

SERCOS header specifies two sub types of SERCOS telegrams:

- **Master data telegram (MDT):** The MDTs transmit data from the master to the slaves;
- **Device telegram (AT):** The ATs transmit data from the slaves to the master.

Furthermore, ISO/IEC 8802-3 Ethernet protocols can be transported.

21.1.2 Real-time telegram types

21.1.2.1 General

Real-time telegrams are transmitted in the real-time part of the communication cycle time (RT channel). They transport mainly command values and actual values. SERCOS defines two types of real-time telegrams (MDT and AT).

21.1.2.2 Master data telegram (MDT)

SERCOS specifies 4 MDTs (MDT0 to MDT3). The MDTs are transmitted by the master and received by each slave. The MDTs contain all information (e.g., synchronisation, command values, digital outputs ...) which is sent from the master to the slaves through the real-time channel.

MDT0 is always transmitted. MDT1 through 3 are transmitted only if required and depend on the total amount of data to be transmitted to the slaves. The master always sends the same number of MDTs during each communication cycle.

21.1.2.3 Device telegram (AT)

SERCOS specifies 4 ATs (AT0 to AT3). The ATs are transmitted by the master with empty data fields. Each slave inserts its data into its allocated data field within the AT. The ATs contain all information (e.g., feedback values, digital inputs ...) which is sent from the slaves to the master as well as between the slaves through the real-time channel.

AT0 is always transmitted. AT1 through 3 are transmitted only if required and depend on total amount of data to be transmitted to the master. The master always sends the same number of ATs during each communication cycle.

21.1.2.4 Cycle time

The following reference values have been determined for the communication cycle time, t_{Scyc} .

$t_{Scyc} = 31,25\mu s, 62,5\mu s, 125\mu s, 250\mu s$ and integer multiples of $250\mu s$ up to $65\,000\mu s$.

This cycle time is allowed to have some jitter. The jitter describes the deviations from the t_{Scyc} value in the distance between two MDT0. J_{tScyc} shall belong to a class as in Table 1.

Table 1 – Synchronisation classes

Synchronisation	Jitter of MDT0 J_{tScyc}
high performance class	$\leq \pm 1\mu s$
low performance class	$\leq \pm 50\mu s$

Therefore, the actual time interval between the MDT0 and the following MDT0 has a minimum value of:

$$j \times t_{Scyc} * 0,9999 - J_{tScyc} \quad (j = 1, 2, 3, \dots),$$

and a maximum value of:

$$j \times t_{Scyc} * 1,0001 + J_{tScyc} \quad (j = 1, 2, 3, \dots).$$

NOTE j is an arbitrary, strictly positive integer, and is not related to the abbreviations.

The factors 0,9999 or 1,0001 take into account the deviation of the communication cycle time t_{Scyc} , compared to the accuracy of the usual crystal oscillators (± 100 ppm). Note that the jitter shall not accumulate over several periods (i.e., the average value shall be zero).

21.1.2.4.1 Telegram transmission times

During the initialization phase, the master inquires for time parameters from the slaves. See subclause 14.2. "Communication phase 2 (CP2)" in IEC 61158-6. With this information, it is possible to calculate a collision-free distribution of transmission time-slots of the telegrams within the RT channel.

The master transmits to each slave the AT transmission starting time, t_1 , as well as the beginning and ending times of the IP channel, t_6 respectively t_7 . These starting times for the transmitting time-slots for the telegrams are defined next.

Jitter has been incorporated in t_1 :

t_1 AT transmission starting time: this is the nominal time interval between the beginning of MDT0 and the beginning of the AT0. This parameter has been determined by the master and is stored in the associated devices as an IDN.

J_{t1} Jitter in t_1 : this is the maximum deviation of the beginning of the AT0. It is the allowed deviation of the time interval t_1 . The actual time interval between the beginning of MDT0 and the beginning of AT0 shall lie between $t_1 - J_{t1}$ and $t_1 + J_{t1}$. J_{t1} shall have the same value as the jitter of MDT0, J_{tsyc} . See Table 1.

t_6, t_7 Time-slot of IP channel (t_6 begin of IP channel, t_7 end of IP channel). Within the IP channel there are no special time-slots. Every participant can send its IP telegrams during this time-slot. The time parameters (t_6 and t_7) are set by the master in communication phase 2 (CP2).

Figure 4 “Access to the transfer medium” (subclause 33.2.2.2.1) in IEC 61158-4 shows the timing of the transmission time-slots.

21.1.2.5 Timing parameters

The following time parameters are characteristics of the network.

t_{rep} time by which the received signal is delayed by a forwarding slave (input to output). This parameter is saved as an IDN in the slave.

t_{cable} time by which the transmitted signal is delayed by the cable (approx., 5 ns/m).

t_{ring} time between the transmitted and received signal at the master. The master measures the ring delay in CP0. The ring delay contains all forwarding and cable delays in the network and is used for synchronisation purposes.

21.1.2.6 MDT partitioning

A service channel and a configurable real-time data field (RTD) are defined in the MDT for each slave. S-0-1013 sets the offset for the service channel. S-0-1009 sets the offset for the real-time data field. S-0-1010 contains the length of the MDT (see Figure 1). These parameters are transmitted by the master to the slaves in CP2.

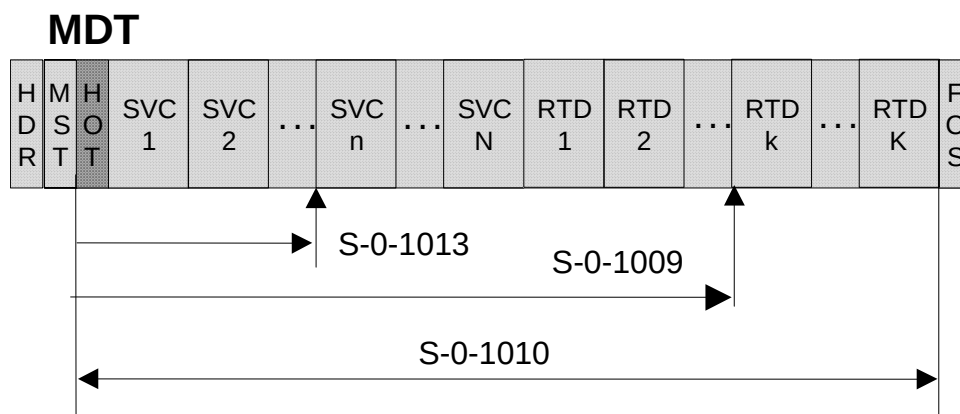


Figure 1 – Partitioning of MDT data fields

21.1.2.7 AT partitioning

A service channel and a configurable real-time data field are defined in the AT for every device. S-0-1014 defines the offset for the service channel. S-0-1011 defines the offset for the

real-time data field. S-0-1012 defines the length of the AT (see Figure 2). These parameters are transmitted from the master to the slaves in CP2.

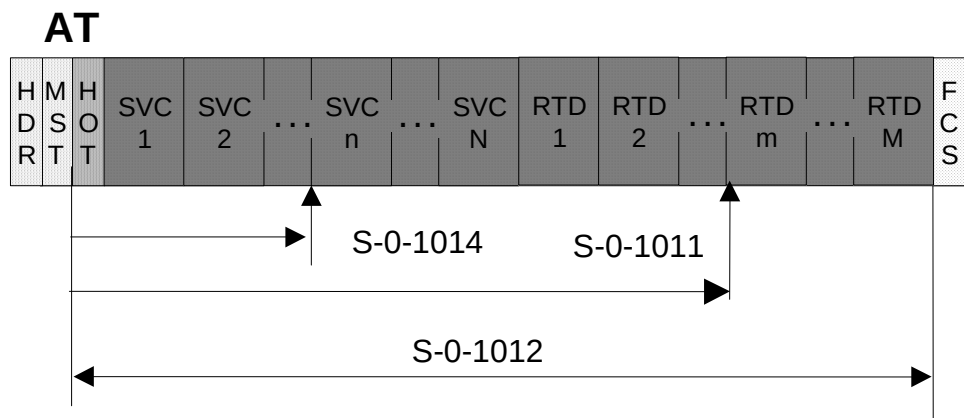


Figure 2 – Partitioning of AT data fields

21.1.3 MDT and AT combinations

The allocations of the service channels (SVC) and the real-time data fields (RTD) in the MDT as well as in the AT are configured with parameters (see Figure 1 and Figure 2). The RTD lengths in the MDTs and the ATs depend on the configuration and may be different. The number of MDTs and ATs may be different. This configuration shall meet the following requirements:

- 1) All service channels shall be configured directly after the hot plug field.
- 2) All real-time data fields shall be configured directly after the last service channel.
- 3) All SVCs of a device shall be transmitted within one telegram (MDT and AT). The telegram shall be filled up with SVCs as much as possible before using the next telegram.
- 4) All RTDs of a device shall be transmitted within one telegram (MDT and AT). The telegram shall be filled up with RTDs as much as possible before using the next telegram.

Figure 3 shows examples of valid telegram combinations of MDTs and ATs.

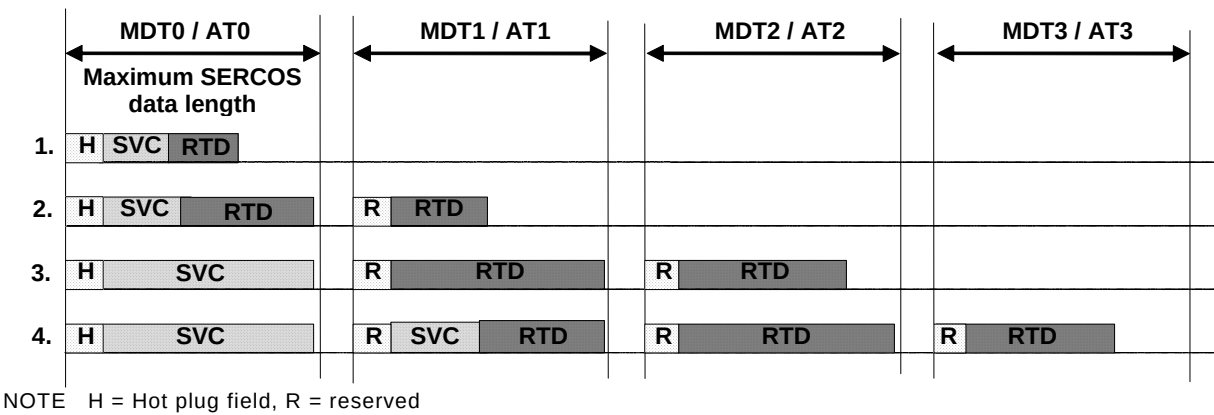


Figure 3 – Examples of valid telegram combinations

Section C – Update of IEC 61158-4

1 Scope and object

1.1 Overview

Type S — A DL-protocol for the Type S DL-service. The maximum system size is 2 links of 255 nodes.

1.2 Specifications

1.2.1 Type S: Additional characteristics

This protocol provides a highly-optimized means of interchanging fixed-length real-time data and variable-length segmented messages between a single master device and a set of slave devices, or between slave devices directly, interconnected in a line or in a ring topology. The ring topology provides for redundant communication paths, and in case of an error it automatically switches to a set of two lines without disturbing the communication. The exchange of real-time data is totally synchronous by configuration and is unaffected by the messaging traffic.

The device addresses are set by the user, e.g., using a selector. Additional devices may be added whenever required, even during operation, without affecting the already existing address selections. The determination of the number, identity and characteristics of each device may be configured or may be detected automatically at start-up.

This protocol provides in addition a standard Ethernet means of interchanging data and files in non real-time way between standard devices such as personal computers and the interconnected devices. This feature provides a way of addressing each individual device even if the device addresses have not yet been set.

2 Normative references

IEC 61491:2002, *Electrical equipment of industrial machines - Serial data link for real-time communication between controls and drives*.

ISO/IEC 8802-3:2001, *Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and Physical Layer specifications*.

5 DL-protocol elements common to multiple DL-protocol Types

5.1 Frame check sequences

Table 1 – FCS length, polynomials and constants by protocol Type

Protocol	Item	Value
Type S	$n-k$	32
	$G(x)$	$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$ (note 1)
	NOTE 1: Refer to ISO/IEC 8802-3 for a thorough description of this polynomial.	

33 Type S: Data Link protocol definition

33.1 General

In this subclause, the telegram structure (frame structure) is described. Telegrams follow the Ethernet standard ISO/IEC 8802-3.

SERCOS telegrams are indicated by the Ethernet type field number (0x88CD).

SERCOS header specifies two sub-types of SERCOS telegrams:

- **Master data telegram (MDT):** The MDTs transmit data from the master to the slaves;
- **Device telegram (AT):** The ATs transmit data from the slaves back to the master.

Furthermore ISO/IEC 8802-3 Ethernet protocols can be transported.

33.2 Data transfer and data link layer

33.2.1 Real-time telegram structure

33.2.1.1 General

Data transmission takes place in telegrams. The general structure of real-time telegrams has been shown in Figure 1.

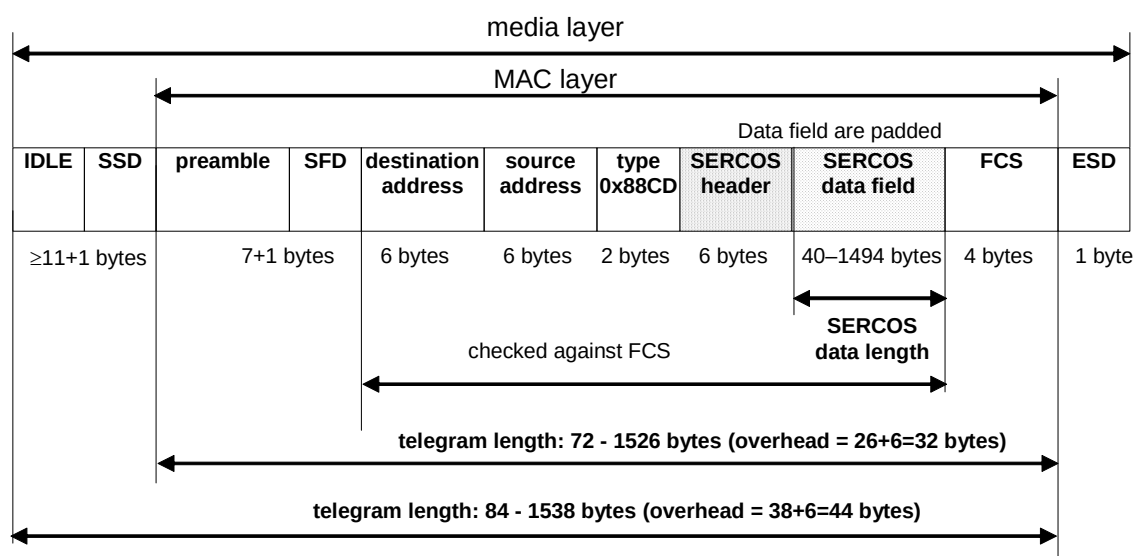


Figure 1 – General telegram structure

33.2.1.2 Telegram delimiters

To receive telegrams correctly the following telegram delimiters are needed:

- Inter Packet Gap (IPG ≥ 12 bytes, IDLE and SSD);
- Preamble (7 bytes);
- Start Frame Delimiter (SFD, 1 byte);
- End Stream Delimiter (ESD, 1 byte).

33.2.1.3 Destination address (DA)

Length: 6 bytes

The master transmits MDTs and ATs to all slaves using the broadcast address 0xFFFFFFFF as destination address.

33.2.1.4 Source address (SA)

Length: 6 bytes

The source address in the real-time telegrams is always the MAC address of the master.

33.2.1.5 Type / length

Length: 2 bytes

The type / length contains the unique SERCOS Ethernet type field number (0x88CD).

33.2.1.6 Data field

Length: 46 bytes to 1500 bytes

All transmitted data is allowed to have arbitrary bit sequences, whereas the total number of bytes follows the rules below.

The data field contains:

- SERCOS specific header (6 bytes) ;
- SERCOS data (40 bytes to 1494 bytes);
- padding bytes shall be inserted whenever the SERCOS data is shorter than 40 bytes.

33.2.1.7 Frame check sequence (FCS)

Length: 4 bytes

A cyclic redundancy check (CRC) is used by the transmit and receive algorithms to generate a CRC value for the FCS field. The frame check sequence (FCS) field contains a 4 byte (32-bit) cyclic redundancy check (CRC) value. This value is computed as a function of the contents of the destination address, source address, type, data and pad (in other words, all MAC layer fields except the preamble, SFD and FCS fields). The FCS is generated by the transmitter. The encoding is defined by the Type S generating polynomial of Table 1, section 5.1.

33.2.2 Timing of the transmission (communication cycle)

33.2.2.1 General

The sequence of transmitting synchronisation, RT-data telegrams and IP telegrams is repeated every communication cycle. The time slots for the RT channel and the IP channel and the transmission time of the AT are transmitted during initialization and are therefore known by each slave. Figure 2 shows two principle arrangements of RT channel and IP channel. Both methods are possible and can be parameterized by the master (see Figure 4). Within the IP channel there are no special time slots. Every participant may send its IP telegrams during this time slot depending upon configuration.

A synchronous collision-free media access control is used in the RT channel. Telegrams are exchanged in fixed communication cycles. The master starts the communication cycle strictly equidistant with the communication cycle time $t_{S_{cyc}}$, by transmitting the MDT0. The next communication cycle starts with the transmitting of the next MDT0.

The MDTs (MDT0 through MDT3) are transmitted as broadcast telegrams to all slaves. The MDT0 contains the synchronisation information and the status of the communication in the MDT MST field. The content of the MDT MST field remains constant during the same communication phase.

The ATs (AT0 through AT3) are transmitted by the master with an empty data field. Each slave inserts its data into its allocated data field within the ATs. The sequence of the device data fields within the ATs is independent of the physical order of the topology as well as the predefined device address. The master is the final recipient of the ATs. Slave units positioned between the master and the transmitting slave transmit the telegrams by means of their forwarding function.

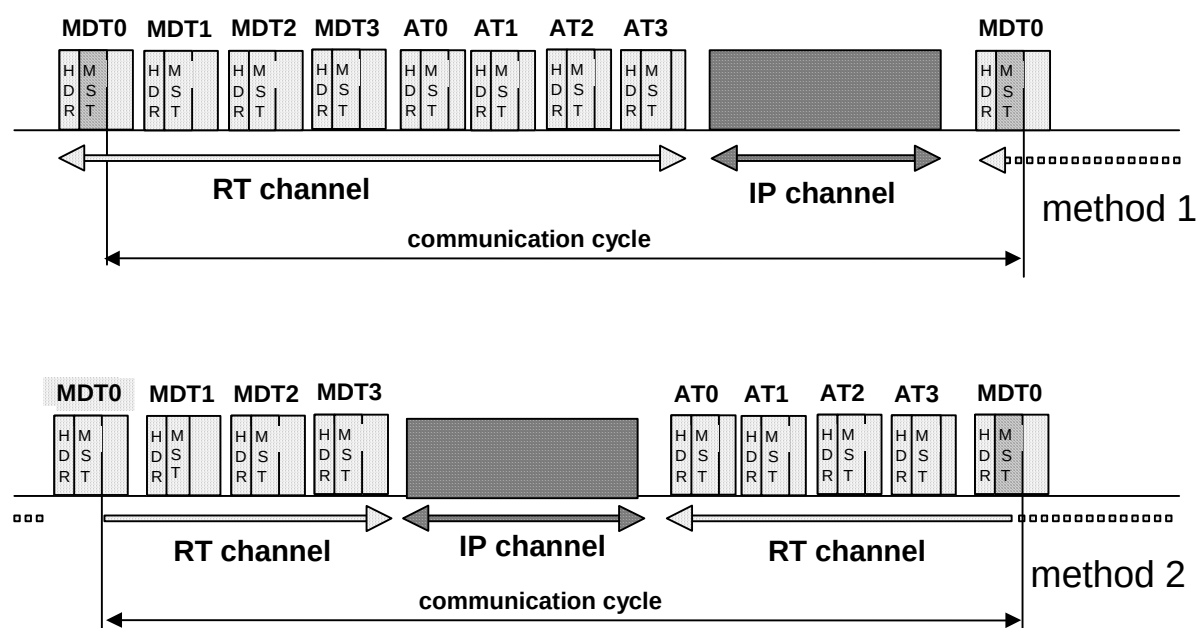


Figure 2 – Telegram sequence in CP3/CP4

33.2.2.2 Transfer medium access

33.2.2.2.1 General

Figure 4 shows the medium access during CP3 and CP4 (cyclic operation). The medium access during CP0 – CP2, which are used during initialization, is given in subclause 14.2 "Initialization of the RT communication" in IEC 61158-6.

In the following text all timings refer to the "beginning of telegram" (see Figure 3). It refers to the edge time of the last binary code 1 of the Start Frame Delimiter (SFD).

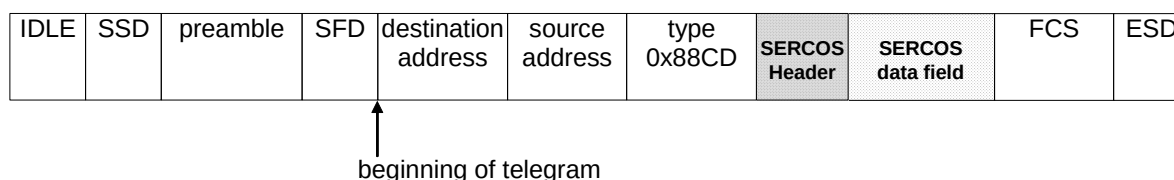


Figure 3 – Beginning of telegram

Medium access is specified by time parameters which shall follow specific limits. Some times are allowed to have a certain amount of jitter.

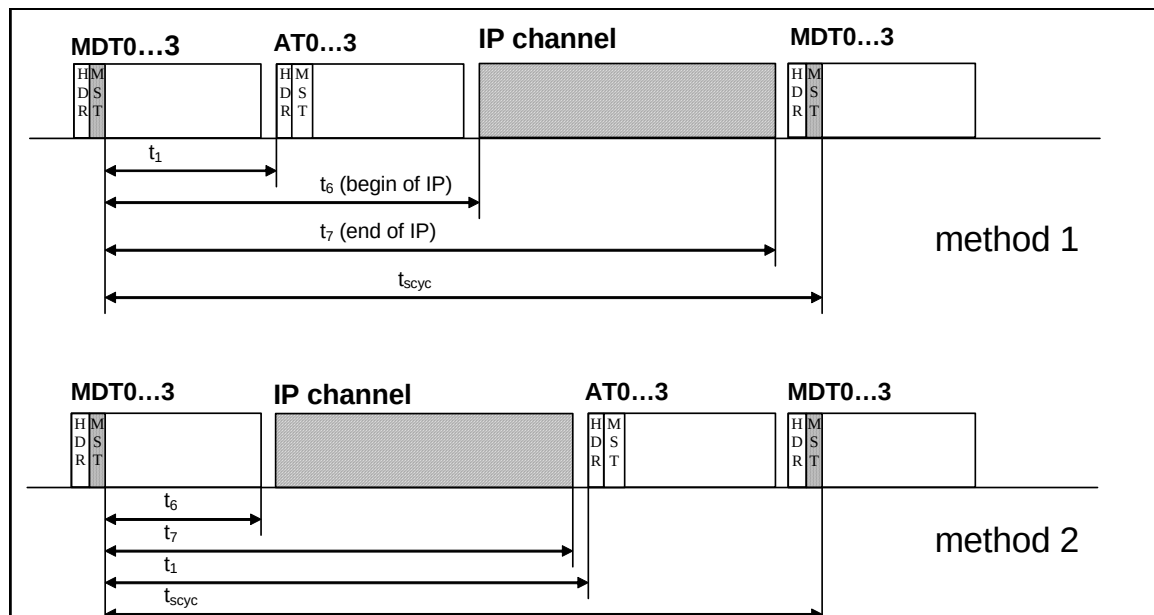


Figure 4 – Access to the transfer medium

NOTE Some control units calculate the new command values only after having received all actual values. In method 1 there is more time available for the calculation of the command values. Method 2 is more appropriate for position control since the control unit can calculate the new command values while still receiving the actual values.

33.3 Protocol structure in the RT Channel

33.3.1 SERCOS telegram structure

33.3.1.1 General

Every SERCOS telegram has a SERCOS header and a SERCOS data field (see Figure 1). Two SERCOS telegram types are specified: MDTs and ATs.

33.3.1.2 SERCOS header

Length: 6 bytes

The SERCOS header contains the SERCOS specific telegram types. The structure is shown in Figure 5. The SERCOS header specifies the SERCOS types only.

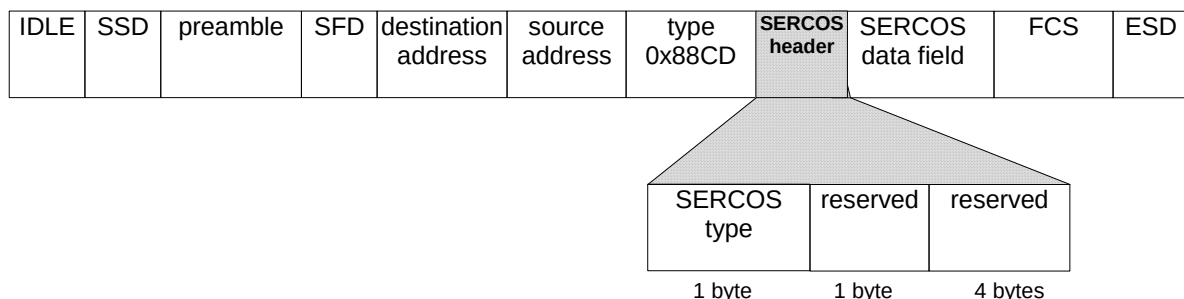


Figure 5 – SERCOS header

The telegram type (see Table 2) is 1 byte long; the following 5 bytes are reserved and specified in the SERCOS telegrams.

Table 2 – SERCOS types

SERCOS type	Description
Bit 7	Primary or secondary telegram
0	Telegram on the primary channel (P-Telegram)
1	Telegram on the secondary channel (S-Telegram)
Bit 6	MDT or AT
0	MDT
1	AT
Bits 5 - 2 = 0	reserved
Bits 1, 0	Telegram number
00	Telegram number 0
01	Telegram number 1
10	Telegram number 2
11	Telegram number 3

NOTE All other bit combinations are reserved.

33.3.2 Device address ADR

The device address ADR shall be in the range $0 \leq \text{ADR} \leq 254$. It is set by the user on the device, e.g., using a selector. No two devices may be set to the same address.

As an exception, device address ADR 0 may occur several times and indicates that no telegrams are being generated by this device. This makes it possible to remove devices logically from the communication (e.g., for testing purposes).

The address value 255 is reserved.

33.3.3 MDT structure

33.3.3.1 General

The MDT contains the MDT MST field and the MDT data field.

33.3.3.2 MDT MST field

33.3.3.2.1 MDT MST field summary

Length: 6 bytes

The SERCOS header of an MDT is called MDT MST (see Figure 6) and contains

- the MDT SERCOS type (see Table 4);
- the MDT phase (see Table 5);
- the CRC (see subclause 33.3.3.2.5).

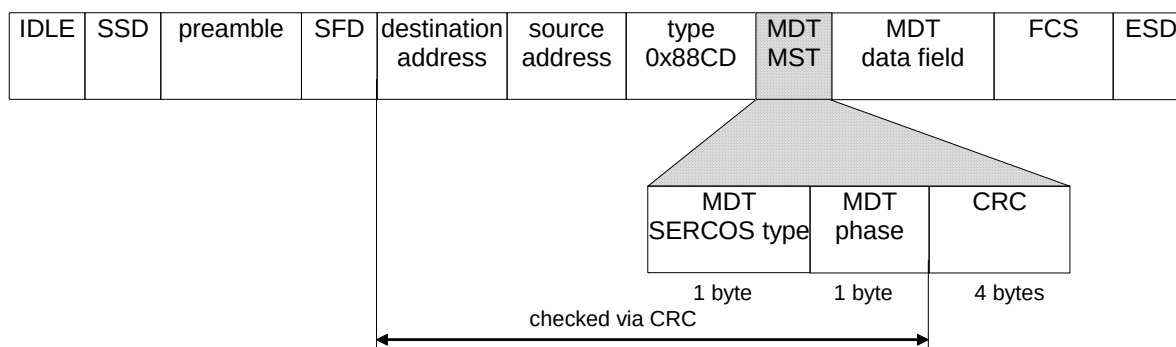


Figure 6 – MDT MST field

33.3.3.2.2 Evaluation of MDT MST in the slave

The MDT MST is generated by the master and evaluated by the slaves. The slave shall evaluate the MDT MST according to Table 3.

Table 3 – MDT MST fields to consider by the slave

	MDT SERCOS type	MDT phase	CRC
MDT0	yes	yes	yes
MDT1	yes	no	no
MDT2	yes	no	no
MDT3	yes	no	no

33.3.3.2.3 MDT SERCOS type

Length: 1 byte

The MDT SERCOS type indicates the various SERCOS telegrams. It is coded in the telegram whether it is an MDT or an AT in the primary or secondary channel. In a line topology the master decides whether the telegrams are marked as primary or secondary telegrams, depending upon configuration.

This type is generated by the master and transmitted in every MDT. Its structure is shown in Table 4.

Table 4 – MDT SERCOS type

MDT SERCOS type	Description
Bit 7	Primary or Secondary telegram
0	MDT on the primary channel
1	MDT on the secondary channel
Bit 6 = 0	MDT
Bit 5-2 = 0	reserved
Bit 1, 0	Telegram number
00	MDT0
01	MDT1
10	MDT2
11	MDT3

33.3.3.2.4 MDT Phase

Length: 1 byte

The phase contains the status of the SERCOS communication. The phase is generated by the master and transmitted in every MDT. The structure is shown in Table 5.

Table 5 – MDT Phase

Phase	Description
Bit 7	Communication phase switching (CPS)
0	current CP
1	new CP
Bit 6-4	reserved
Bit 3-0	Communication phase (CP)
0000	CP0
0001	CP1
0010	CP2
0011	CP3
0100	CP4
0101 - 1111	reserved

NOTE All other bit combinations are reserved

33.3.3.2.5 Cyclic redundancy check (CRC) of MDTs

Length: 4 bytes

The cyclic redundancy check (CRC) is used by the transmit and receive algorithms to generate a CRC value for the CRC field. The CRC field contains a 4 byte (32-bit) cyclic redundancy check (CRC) value. This value is computed as a function of the contents of the source address, destination address, type/length, SERCOS type and phase. The CRC is generated by the master and transmitted in every MDT (MDT0 to MDT3). This CRC is used for synchronisation purposes in MDT0 only. The encoding is defined by the Type S generating polynomial of Table 1, section 5.1.

33.3.3.3 MDT Data field**33.3.3.3.1 General**

In the data field the telegram data are transmitted from the master to all slaves.

The MDT data field (see Figure 7) contains 2 or 3 fields:

- (always) the MDT hot-plug field (see Figure 8);
- (optionally) the MDT service channel field (see Figure 9) for all devices;
- (optionally) the MDT real-time data field (see Figure 11) for all devices.

Subclause 21.1.3 “MDT and AT combinations” in IEC 61158-3 shows examples of valid MDT data fields.

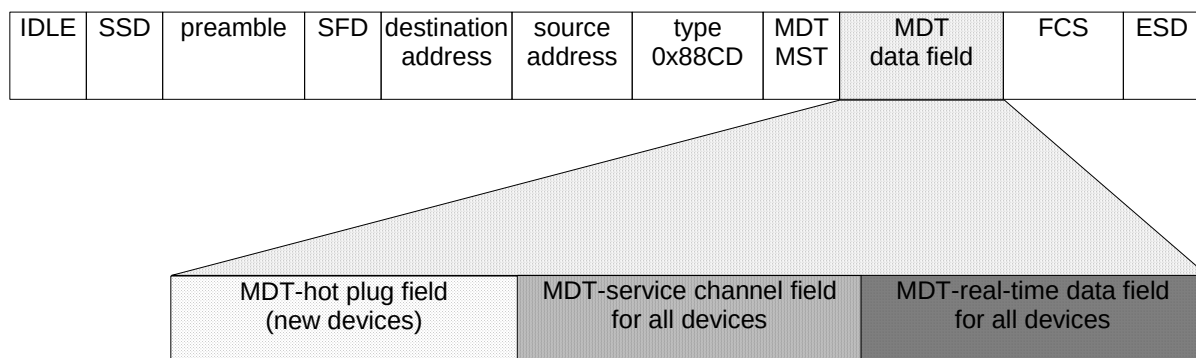


Figure 7 – MDT data field

33.3.3.3.2 MDT Hot plug field

33.3.3.3.2.1 MDT Hot plug field summary

Length: 8 bytes

The MDT hot plug field (see Figure 8) contains:

- the device address (see Table 6);
- the MDT service channel control (see Table 7);
- the MDT service channel INFO (see subclause 33.3.3.3.2.3).

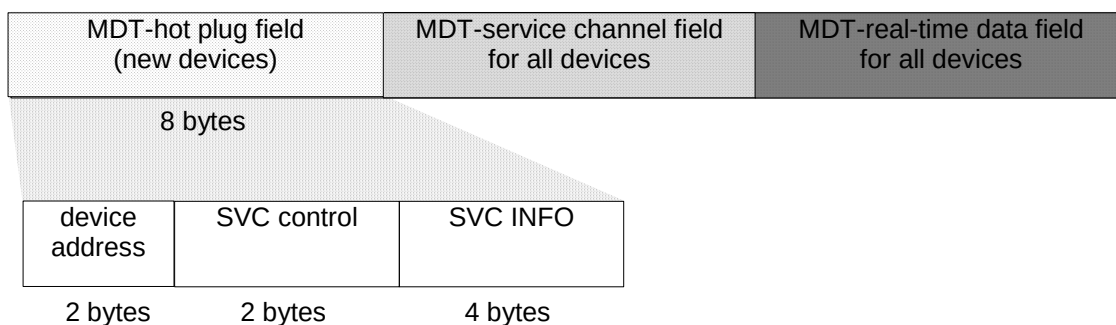


Figure 8 – MDT Hot plug field

33.3.3.3.2.2 Device address

Length: 2 bytes

The structure of device address ADR is shown in Table 6.

Table 6 – Device address

Device address	Description
Bit 15-8	Reserved
Bit 7-0	Device address
0	Logical device removal (see subclause 33.3.2)
1 - 254	Device addresses for operation
255	Reserved (see subclause 33.3.2)

33.3.3.3.2.3 SVC control and SVC INFO

Refer to the MDT service channel field as described in subclause 33.3.3.3.3.

33.3.3.3.3 MDT service channel field

33.3.3.3.3.1 MDT service channel field summary

Length: 6 bytes per device

The MDT service channel field (see Figure 9) contains all service channels (SVC) of the configured devices. Each device has an own service channel. The service channel for each device contains:

- the MDT service channel control (see Table 7);
- the MDT service channel INFO.

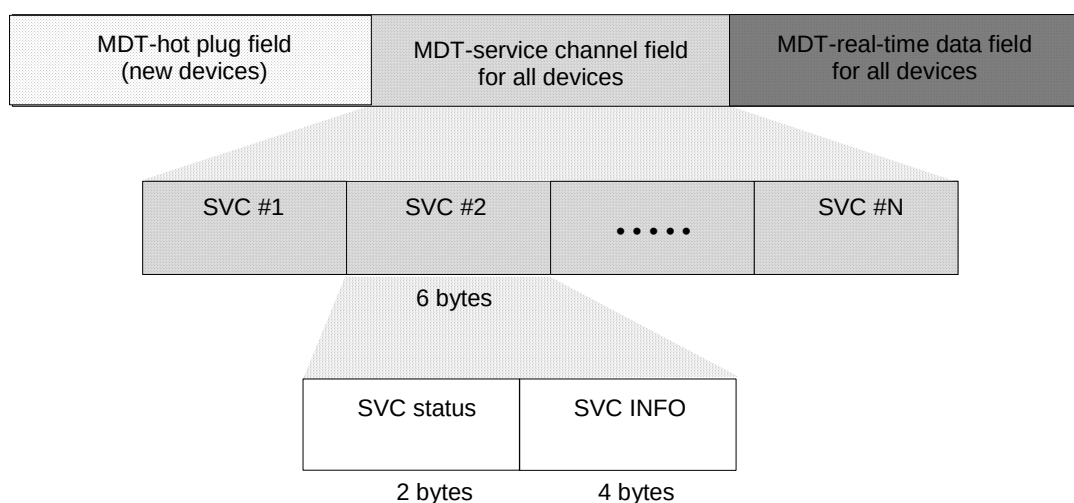


Figure 9 – MDT Service channel

33.3.3.3.3.2 SVC control

Length: 2 bytes

The structure of service channel (SVC) control is shown in Table 7.

Table 7 – Service channel control

SVC control	Description
Bit 15-6	Reserved
Bit 5-3	Data block elements (see subclause 14.4.2 “Service channel transport mechanism” in IEC 61158-6)
000	Element 0: Closed SVC or transmission cancellation in progress
001	Element 1: IDN of operation data. The SVC is closed for the previous IDN and opened for the new IDN
010	Element 2: Name of operation data
011	Element 3: Attribute of operation data
100	Element 4: Unit of operation data
101	Element 5: Minimum value of operation data
110	Element 6: Maximum value of operation data
111	Element 7: Operation data
Bit 2	End of element transmission
0	Transmission in progress
1	Last transmission
Bit 1	R/W
0	Read SVC INFO
1	Write SVC INFO
Bit 0	MHS
0/1	SVC transport handshake of the master (toggle bit)

Note: all other bit combinations are reserved

33.3.3.3.3 SVC INFO

Length: 4 bytes

The structure of service channel (SVC) INFO is shown in Figure 10. The SVC INFO is the container for SVC data exchange from the master to a slave which takes place in steps in special data fields of the MDT. If only 2 bytes are transmitted in a step, then the value is in the low word. In this case the high word value shall be don't care.

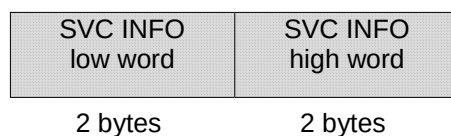


Figure 10 – SVC INFO

33.3.3.3.4 MDT real-time data field

33.3.3.3.4.1 General

The MDT real-time data field (see Figure 11) contains all real-time data of the configured devices. Each device has its own real-time data field and contains:

- the device control (see Table 8);
- the configured real-time data (e.g., command values, ...).

33.3.3.3.4.2 Device control

Length: 4 bytes

The structure of device control is shown in Table 8.

Table 8 – Device control

Device control	Description
Bits 31-16	Reserved
Bit 15 - 8	Reserved for application profiles
Bit 7	Real-time control bit 2 (S-0-0302)
Bit 6	Real-time control bit 1 (S-0-0300)
Bits 5 - 0	Reserved

Note: all other bit combinations are reserved

33.3.3.3.4.3 Configurable MDT RT-data

The configurable real-time data field of the MDT (see Figure 11) is specified in subclause 16.2.1 “Configurable MDT RT-data” of IEC 61158-5.

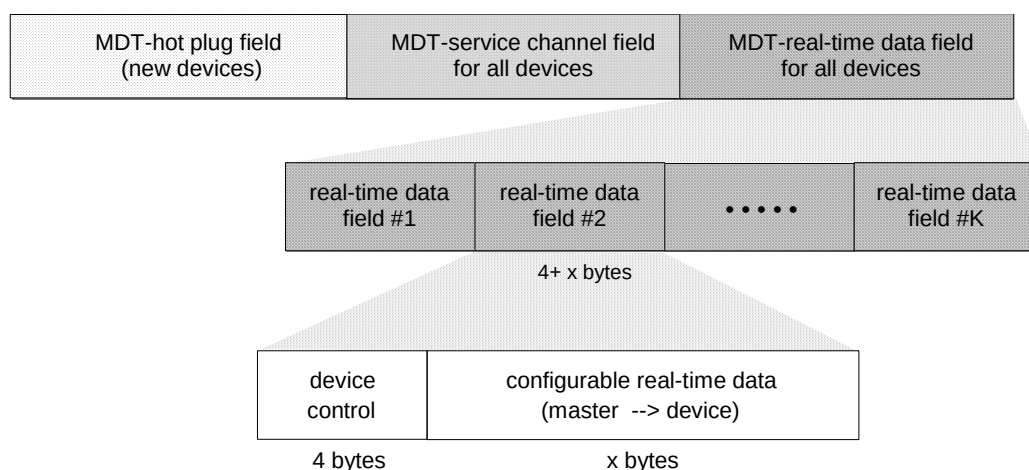


Figure 11 – MDT Real-time data

33.3.4 AT structure

33.3.4.1 General

The AT contains the AT MST field and the AT data field.

33.3.4.2 AT MST field

33.3.4.2.1 AT MST field summary

Length: 6 bytes

The SERCOS header of the AT is called AT MST (see Figure 12) and contains the same information as the MDT MST,

- AT SERCOS type (see Table 10);
- AT phase (see 33.3.4.2.4);
- CRC (see 33.3.4.2.5).

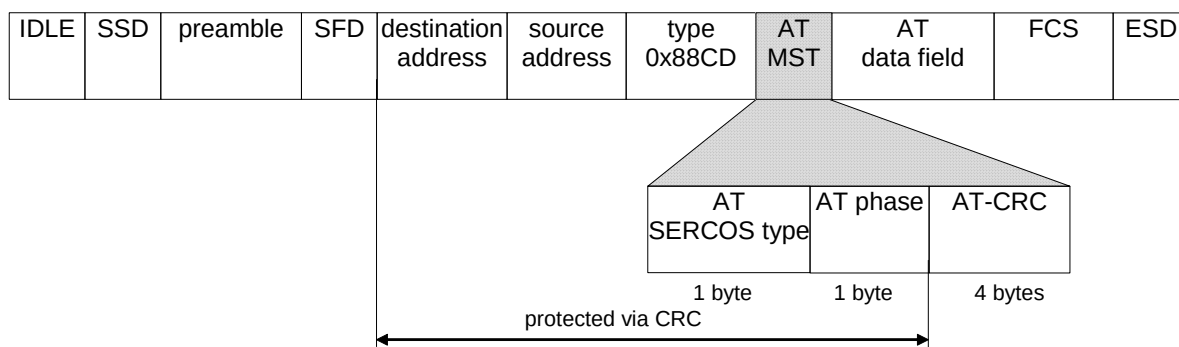


Figure 12 – AT MST field

33.3.4.2.2 Evaluation of AT MST in the slave

The AT MST is generated by the master and evaluated by the slaves. The slave shall evaluate the AT MST according to Table 9.

Table 9 – AT MST fields to be considered by the slave

	AT SERCOS type	AT Phase	CRC
AT0	yes	no	no
AT1	yes	no	no
AT2	yes	no	no
AT3	yes	no	no

33.3.4.2.3 AT SERCOS type

Length: 1 byte

The AT SERCOS type indicates the various SERCOS telegrams. The SERCOS type of all ATs is generated by the master. The structure is shown in Table 10.

Table 10 – AT SERCOS type

AT SERCOS type	Description
Bit 7	Primary or Secondary telegram
0	AT on the primary channel
1	AT on the secondary channel
Bit 6 = 1	AT
Bit 5 – 2 = 0	Reserved
Bit 1, 0	Telegram number
00	AT0
01	AT1
10	AT2
11	AT3

33.3.4.2.4 AT Phase

Length: 1 byte

The phase contains the status of the SERCOS communication. The phase of all ATs is generated by the master and has the same value as for the MDT. The phase of an AT is not evaluated by the slave (see Table 9).

33.3.4.2.5 Cyclic redundancy check (CRC) of AT

Length: 4 bytes

The cyclic redundancy check (CRC) is used by the transmit and receive algorithms to generate a CRC value for the CRC field. The CRC field contains a 4 byte (32-bit) cyclic redundancy check (CRC) value. This value is computed as a function of the contents of the source address, destination address, type/length, telegram AT SERCOS type and phase. The AT-CRC is generated by the master. The AT-CRC is not evaluated by the slave (see Table 9). The encoding is defined by the Type S generating polynomial of Table 1, section 5.1.

33.3.4.3 AT Data field

33.3.4.3.1 General

In the AT data field the telegram data are transmitted from all slaves to the master.

The AT data field (see Figure 13) contains 2 or 3 fields:

- (always) the AT hot plug field (see Figure 14);
- (optionally) the AT service channel field (see Figure 15) for all devices;
- (optionally) the AT real-time data field (see Figure 16) for all devices.

Subclause “MDT and AT combination” 21.1.3 in IEC 61158-3 shows examples of valid AT data fields.

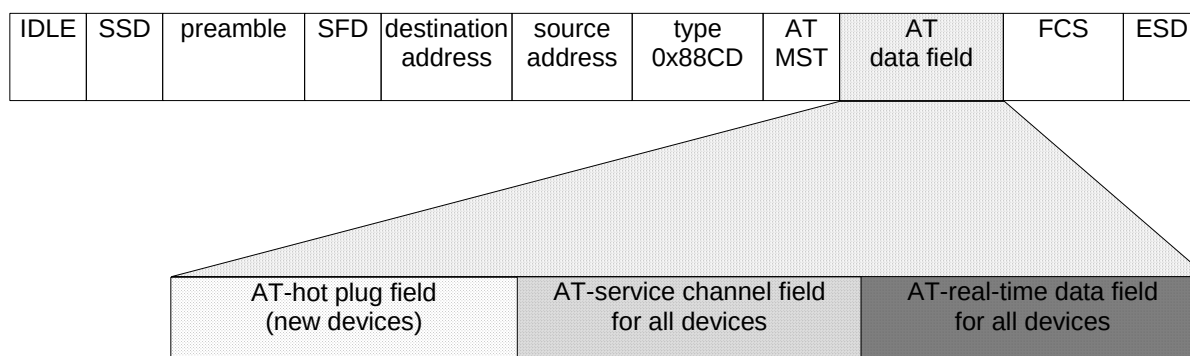


Figure 13 – AT data field

33.3.4.3.2 AT Hot plug field

33.3.4.3.2.1 AT Hot plug field summary

Length: 8 bytes

The hot plug field as shown in Figure 14 contains:

- the device address (see Table 6);
- the AT service channel status (see Table 11);
- the service channel INFO.

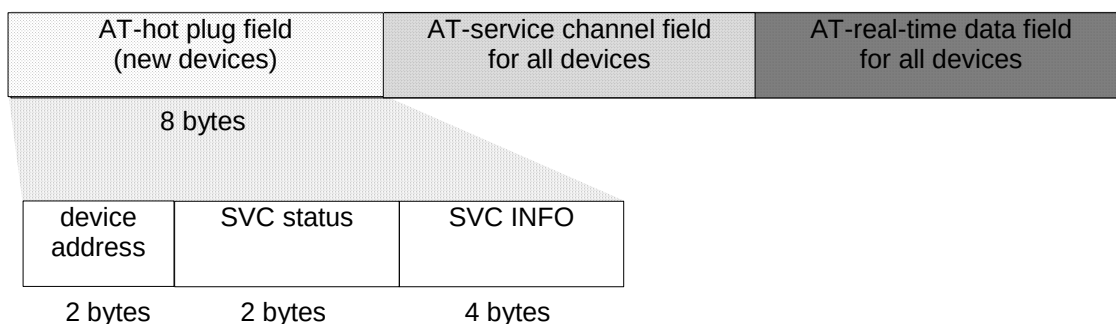


Figure 14 – AT Hot plug field

33.3.4.3.2.2 Device address

See 33.3.3.3.2.2.

33.3.4.3.2.3 SVC status and SVC INFO

The structure of the service channel (status and INFO fields) is described in subclause 33.3.4.3.3.

33.3.4.3.3 AT service channel fields

33.3.4.3.3.1 AT service channel fields summary

Length: 6 bytes per device

The AT service channel field contains all service channels of the configured devices. Each device has its own dedicated service channel. The service channel for each device contains:

- the service channel status (see Table 11);
- the service channel INFO.

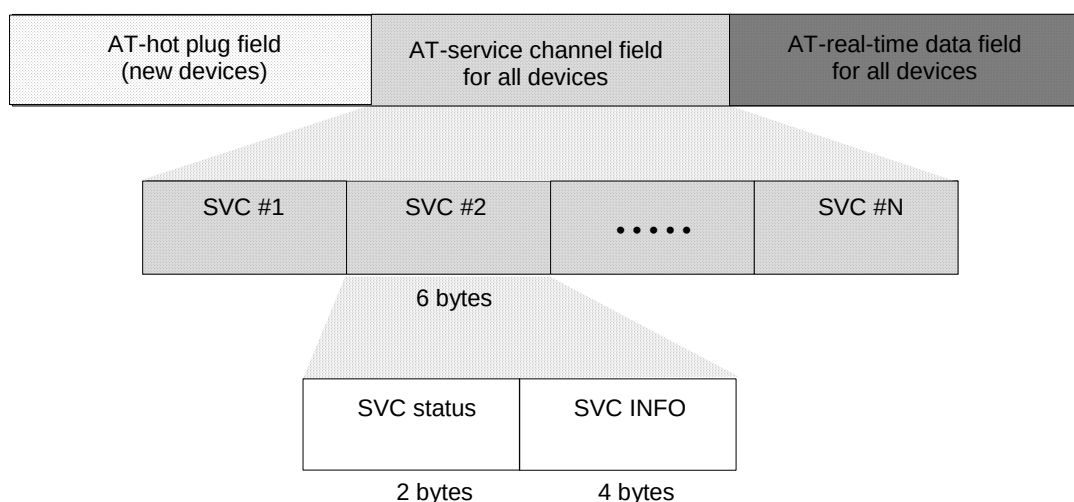


Figure 15 – AT Service channel

33.3.4.3.3.2 SVC channel status

Length: 2 bytes

The structure of service channel (SVC) status is shown in Table 11.