HYDAC ELECTRONIC

Temperature transmitters

ETS 4100 CAN
ETS 4100S CAN

Protocol Description

CANopen

Modification: 000

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Preface

This documentation describes the intended use of the product within a higher-level control system. It will help you to get acquainted with the provided communication interface and assist you in obtaining maximum benefit in the possible applications for which it is designed.

The specifications given in this documentation represent the state-of-the-art of the product at the time of publishing. Modifications to technical specifications, illustrations and dimensions are therefore possible.

> The electronic document version contains many **active cross-references**, which are written in italics.

HYDAC ELECTRONIC GMBH

Technical documentation dept.
Hauptstrasse 27
66128 Saarbruecken
Germany

Phone: +49(0)6897 / 509-01
Fax: +49(0)6897 / 509-1726

Email: electronic@hydac.com

Quick Start

General information

General product information, definition of the scope of applications, symbols used, as well as abbreviations.

Quick guide

In this chapter, the experienced users will find the factory pre-set process data signals as well as the device's own specifications supported by the measurement system.

Process data

Description of all signals provided as process data by the measurement system.

Parameters

Adjustable parameters for the communication or the functions of the measurement system.

Protocol description CANopen

Description of the protocol used. This chapter describes principles and examples which help to facilitate the communication with the measurement system.

Subsequent Chapters

All chapters subsequent to the protocol description provide additional and useful information for the commissioning and application of the measurement system.

1. General information

This protocol description, including the illustrations contained therein, is subject to copyright protection. Use of this document by third parties in contravention of copyright regulations is forbidden. Reproduction, translation as well as electronic and photographic archiving and modification require the written permission of the manufacturer. Offenders will be liable for damages.

Before commissioning the product, please read the related operating instructions as well as this protocol description. Ensure that the unit described, hereinafter referred to as the measurement system, is suitable for your application.

> Before each startup, installation or replacement, the measurement system including related accessories has to undergo a visual check for damage.

> If the instrument is not handled correctly, or if the operating instructions and specifications are not adhered to, damage to property and/or personal injury can result.

1.1. Scope of application

This protocol description exclusively applies to the following measurement system types for fluid temperature measurement without increased demands upon functional safety. The products covered by this description can be identified by means of the following model code structure:

- CANopen: **ETS 41**xx–**F11**–xxx–**000**
- CANopen: **ETS 41**xxS–**F11**–xxx–**000**
    - Only the positions in the model code marked by "x" can be freely occupied using the attributes listed in the data sheet.

The products are components of a system or machine, with lasered type labels.

The following documentation should therefore always be read together:

- The operator's system and machine-specific operating manuals
- The related operating instructions
- This protocol description for CANopen

1.2. Exclusion of liability

This protocol description was prepared to the best of our knowledge. Nevertheless and despite the greatest care, it cannot be excluded that mistakes could have crept in. Therefore please understand that in the absence of any provisions to the contrary hereinafter our warranty and liability – for any legal reasons whatsoever – are excluded in respect of the information in this operating manual.

	In the event of translation, only the original version of the protocol description in German is legally valid.

In particular, we shall not be liable for lost profit or other financial loss. This exclusion of liability does not apply in cases of intent or gross negligence. Moreover, it does not apply to defects which have been deceitfully concealed or whose absence has been guaranteed, nor in cases of culpable harm to life, physical injury and damage to health. If we negligently breach any material contractual obligation, our liability shall be limited to foreseeable damage. Claims due to the product liability shall remain unaffected.

1.3. Symbols

In the following section we have listed all symbols used and their meaning.

	The symbol means that the circumstances described here are forbidden *(general prohibition sign according to DIN EN ISO 7010).*
	The symbol means that death, personal injury or severe damage to property could occur if the precautions stated here have not been adhered to or have not been taken *(general warning sign according to EN ISO 7010)*.
	The symbol indicates important information or features and application suggestions for the product used.
	The symbol means that appropriate ESD-protective measures must be observed according to DIN EN 100 015-1. (Cause of a potential equalisation between body and device-mass as well as the housing-mass by means of a high-impedance resistance (approx. 1 MOhm) e.g. with a standard ESD wrist strap).

1.4. Abbreviations used and definitions

List of abbreviations used and glossary of terms which are not common.

Abbreviation	**Description**
ACC	**Acc**elerometer
ASCII	**A**merican **S**tandard **C**ode for **I**nformation **I**nterchange
Baud rate	Communication speed of the bus system [bit/s]
CAN	**C**ontroller **A**rea **N**etwork
CANopen	**CAN** based communication protocol for automation tasks

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Abbreviation	Description
CiA	**C**AN **I**N **A**UTOMATION international users' and manufacturers' group CiA (EU trademark 00 710 98 46)
DIN	**D**eutsches **I**nstitut für **N**ormung e.V. (DIN - German Institute for Standardisation)
DLC	**D**ata **L**ength **C**ode; data length in a CAN message
ECU	**E**lectronic **C**ontrol **U**nit Superordinate control, e. g. PLC or mobile control unit
EDS	**E**lectronic **D**ata **S**heet Electronically readable description of the CANopen OD
EC	**E**uropean **C**ommunity
EMC	**E**lectro **M**agnetic **C**ompatibility
EN	European standard
ESD	**E**lectro **S**tatic **D**ischarge
ETS	**E**lectronic **T**emperature **S**ensor; temperature sensor by HYDAC ELECTRONIC GMBH
Flash	Permanent memory for application software and persistent data
GYRO	**Gyro**scope
HTT	**H**YDAC **T**emperature **T**ransmitter; Temperature sensor by HYDAC ELECTRONIC GMBH
IEC	**I**nternational **E**lectrotechnical **C**ommission
ISO	**I**nternational **O**rganization for **S**tandardization
J1939	CAN based communication protocol for vehicle manufacturing (SAE J1939)
LSS	**L**ayer **S**etting **S**ervices Protocol for the setting of the Node-ID, the BAUD rate and the LSS address
MEMS	**M**icro-**E**lectro-**M**echanical **S**ystem
NEC	**N**ational **E**lectrical **C**ode
NMT	**N**etwork **M**anagemen**t**; management of the network accounts
Node ID	CANopen Node address
OD	**O**bject **D**ictionary; Object dictionary of all communication objects provided by the product
PC	**P**ersonal **C**omputer
PDO	**P**rocess **D**ata **O**bject Object for the transmission of process data
RAM	**R**andom **A**ccess **M**emory; volatile, fast memory
RMS	**R**oot **M**ean **S**quare

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Abbreviation	Description
RPDO	**R**eceive **PDO**; process data received by the CAN nodes
Rx / Tx	**Rx: R**eceiver / **Tx: T**ransmitter; Direction of the data flow from the perspective of a superordinate controller Tx: ECU → Device, Rx: Device → ECU
SAE	**S**ociety of **A**utomotive **E**ngineers
SDO	**S**ervice **D**ata **O**bject Object for the access to the CANopen OD
PLC	**P**rogrammable **L**ogic **C**ontroller
SRDO	**S**afety-**R**elevant **D**ata **O**bject Object for the safe transmission of values for CANopen Safety
TPDO	**T**ransmit **PDO**; process data sent from the CAN node
UL	**U**nderwriters **L**aboratories
VDC	Direct current
VDE	**V**erein **D**eutscher **E**lektrotechniker (German Electrical Engineers Association)

1.5. General document structure

This document has a defined structure. Subsequent to each chapter title, there will be a short description of the chapter content.

It is not only our aim to show the users an efficient way to find a specific response to their inquiry, but also to provide the users with less prior knowledge with the required information to ensure successful use of the product.

1.5.1. Chapter structure

The general structure is divided into the following essential chapters.

- ***2 Basic Information***

  General information explaining the function principle of a measurement system equipped with a communication interface.

- ***3 Product interface***

  All the product specific characteristics are described here. Certain sections of this description may be repeated in the protocol description or contradicted in the protocol description if the measurement system described herein deviates in parts from the general protocol description or if the properties of the protocol description are supplemented.

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- ***4 Protocol description CANopen***

  The general protocol description provides you with all information required for a successful communication. It explains, for instance, how the process data is transmitted with this specific communication protocol. In addition, it explains how to change the measurement system configuration settings.

1.5.2. Notes on using this documentation efficiently

In order to get quick access to particular subjects, this document is linked with active cross-references (hyperlinks). These are formatted in *italics*.

This chapter *3.1 Quick guide* is designed to lead you to answers to the most frequently asked questions as quickly as possible.

Symbols and abbreviations are explained in chapters *1.3 Symbols* and *1.4 Abbreviations used and definitions.*

The display of numeric figures is explained in chapter *2.2 Representation of numeric figures.*

Technical English terms are placed between quotation marks ("..").

1.6. Changes in technical terms in the context of "political correctness"

HYDAC Electronic GmbH continuously strives to respect human rights and every individual's dignity in any context. However, when it comes to communication technology, one technical term is still very common: "Master – Slave".

In order to avoid this archaic and discriminating expression, the term has been replaced wherever possible in this documentation using the following substitution: "Master – Device" ("Device" instead of "Slave"). The only exceptions are terms which are used in this form in official documentation. These exceptions are only used to make it easier for the reader to understand the connection between this documentation and the official documents.

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2. Basic Information

The following sections will explain general, non-product specific information for a better understanding of the functioning principle of a measurement system with a communication interface.

2.1. General communication characteristics

In general, the measurement systems are the end nodes within a communication network. They do not take control of their higher-level network themselves. However, these devices are able to generate and send information spontaneously. This means that the measurement systems mainly serve as a data source - they generate process data.

The following types of information can be generated and processed by the measurement system:

- *Process data* current actual or nominal values
- *Parameters* System data for the device identification or configuration
- *Events* Information on particular events, such as errors

The information types listed here are explained in more detail in the following chapters.

2.2. Representation of numeric figures

The figures without additional markings are displayed as numeric figures with decimals (number basis 10). For a more simple display of data blocks, however, hexadecimal representation is also very commonly used (number basis 16). In our document, the hexadecimals are generally marked by an "h" as a suffix.

Decimal numbers, when displayed in a mixed representation, are marked with the additional suffix "d".

Binary numbers (number basis 2) are marked by suffix "b".

- **12h** 12 hexadecimal → 18 decimal
- **A2h** A2 hexadecimal → 162 decimal
- **16d** 16 decimal → 10 hexadecimal
- **66** 66 decimal → 42 hexadecimal
- **10b** 10 binary → 2 decimal

Note

In other documentations, i.e. EDS files, you will also frequently encounter the format "**0**x1042". Here, the prefix "0x" marks the subsequent number as a hexadecimal.

When describing the entries in the OD (see chapter *4.5 The Object* Dictionary), the index is always shown in hexadecimal notation, but without any particular markings.

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2.3. Bit order

The measurement systems use the "Little Endian" format for the transmission of their numeric values. In this representation of numeric values, the lowest bit (LSB; "least significant bit") will be stored and added to the lowest data block address.

2.3.1. Counting principle for bit and byte position in the data block

In practice, there are different ways of counting in order to define the position of a particular piece of data within a data block. For this documentation, the following way of counting has been defined:

- **Bit** positions within a continuous data block start with **0.**
- **Byte** positions within a data block start with **0.**

2.3.2. Representation of a 16 bit integer number within a data block

The following example will explain the storage position of the "Little Endian" format. For this purpose, the transmission of an *INTEGER16*, e.g. of a 16 bit signed integer number, is shown in the data block of a CAN message (8 bytes).

The value to be transmitted will be shown as a hexadecimal number in order to show more clearly how the number is assigned to the bytes within the data block.

Numerical value decimal			4711d				
Numerical value hexadecimal			**1267**h				
Numerical value binary			0001 0010 0110 0111				
Data bytes of the CAN message							
Byte 0	**Byte 1**	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
INTEGER16		User definable	User definable	User definable	User definable	User definable	User definable

Using the "Little Endian" bit order, the least significant byte of the numeric value (67h in our example) is copied to the least significant byte of the data block (marked blue). At the same time, the least significant bit (LSB) is located in the least significant bit of the first byte (marked red). For better clarity, the data ranges which are not used, byte 2 to 7, are not shown.

Byte 0								**Byte 1**								Data bytes of the CAN message
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Bit position
67h								**12**h								Content hexadecimal
0	1	1	0	0	1	1	1	0	0	0	1	0	0	1	0	Content binary

2.3.3. Display of a 32 bit integer number within the data block

In the following example, the transmission of an *INTEGER32*, e.g. of a 32 bit signed integer numeric value within a data block of a CAN message (8 bytes) is shown in the "Little Endian" format.

Numerical value decimal				-2011871471d			
Numerical value hexadecimal				**88154711**h			
Byte 0	**Byte 1**	**Byte 2**	**Byte 3**	Byte 4	Byte 5	Byte 6	Byte 7
INTEGER32				User definable	User definable	User definable	User definable
11h	**47**h	**15**h	**88**h	User definable	User definable	User definable	User definable

2.4. Data types

For all data types, the display of numeric values described in the chapter *2.3 Bit* order is applicable to the storage within data blocks.

2.4.1. INTEGER

INTEGER is the term for signed whole numbers whose data length may vary. Negative figures will be specified by a two's complement [NOT(<numeric value>) + 1]. The data length is specified in bits and is added as a suffix right after the data type identifier. If the most significant bit is an INTEGER figure 1, this will be negative.

Therefore, INTEGER16 means it is a signed whole number whose data length is 16 bits.

Data type	Length [Bit]	Min.	Max.
INTEGER8	8	-128	+127
INTEGER16	16	-32,768	+32,767
INTEGER32	32	-2,147,483,648	+2,147,483,647

For the illustration of data in a data block of more than 1 byte of length, the bit order has to be paid attention to; see chapter *2.3 Bit* order.

2.4.2. UNSIGNED

UNSIGNED specifies unsigned whole numbers. This means that only positive figures can be displayed using this data type. The data length in bytes is added as a suffix.

UNSIGNED32 is a whole numeric value without a sign and with a data length of 32 bits.

Data type	Length [Bit]	Min.	Max.
UNSIGNED8	8	0	+255
UNSIGNED16	16	0	+65,535

Data type	Length [Bit]	Min.	Max.
UNSIGNED32	32	0	+4,294,967,295

For the illustration of data in a data block of more than 1 byte of length, the bit order has to be paid attention to; see chapter *2.3 Bit order*.

2.4.3. BOOLEAN

The data type BOOLEAN is used to illustrate binary signals. These are signals which are not able to adopt more than two logical states. The data length in the memory may vary. If an individual binary signal is stored in the memory, the data type is usually an *UNSIGNED8*. Should the binary signal be a part of a BITFIELD, the data length is 1 bit.

Value	DE	EN	Meaning
0	FALSCH	FALSE	Signal or property is not active.
1 (≠ 0)	WAHR	TRUE	Signal or property is active. NOTE: In some implementations, each value unequal to "0" is considered as TRUE.

2.4.4. BITFIELD

The data type UNSIGNED is often used for the display of bitfields. In this case, each bit of the piece of data has its own signification, although in many cases, not all bit positions are used. Each bit of the BITFIELD therefore corresponds with a signal of the data type *BOOLEAN*. The significance of each individual bit is explained in the related description.

Status signals are often displayed as a bitfield. The representation of the content of a bit-field is usually in binary format, i.e. bit-oriented.

The relevant characteristic is active if the bit which is related to the characteristic is active, which means it has the binary numeric value of 1 (TRUE).

In the case of a bitfield, several identifiers can be set synchronously. Therefore, when evaluating an individual identifier, appropriate masking should be applied for the bit field.

The comparison with a simple constant may fail when there are a combination of identifiers.

Bit positions which are unused may take on fixed values (0/1), depending on internal application states, or shift between the states. For a reliable evaluation, these bit positions should therefore be ignored.

Example of a BITFIELD

Bit	Meaning	Data type
0	Temperature compensation inactive	*BOOLEAN*
1	Device in movement	*BOOLEAN*
2	Reserved	
3	Serious error	*BOOLEAN*
4	Reserved	
5	Reserved	
6	Reserved	
7	Reserved	

Example of the contents and the signification

0000 0010b = 02h = 2d → identifier "device in movement" is active.

0000 1010b = 0Ah = 10d → identifier "device in movement" and "serious error" are active at the same time.

2.4.5. REAL32

REAL32 is a signed floating point number with a data length of 32 bits. These types of numbers are subdivided into one signed bit (1 bit), one mantissa (23 bits) and one exponent (8 bits). With this numeric value, the non-negative integer numbers can be displayed with sufficient accuracy. The representation below corresponds with IEEE754.

Data type	Length [Bit]	Min.	Max.
REAL32	32	-3,40282347E38	+3.40282347E38

2.4.6. ARRAY

ARRAY is a data type containing a variety of different entries/values. In an ARRAY, the entries are all of the same data type. The value entries in an ARRAY have the same signification but do not have the same content, i.e. a list of all the recently recorded device error numbers. For the individual entries, the simple data types described above, such as *UNSIGNED32*, are used.

In the protocol described here, the first entry of the ARRAY indicates the number of existing entries. In an ARRAY, a maximum of 255 entries is allowed. This entry always has a sub-index of 0 and is handled in a special way.

The individual value entries are accessed via a sub-index. The first sub-index for a value entry is 1. If a sub-index is accessed which is of higher value than the content of the sub-index 0 (number of valid ARRAY entries) an error message will occur.

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2.4.6.1. Example ARRAY

The following example shows the structure of an ARRAY in the OD, see chapter*The Object Dictionary*.

Index	Sub	Value	Name	Type	Access	Data type
1003h			*Pre-defined error field*	ARRAY		
1003h	**0**	4	Number of errors	VAR	rw	UNSIGNED8
1003h	**1**	1001	Standard error field 1	VAR	ro	UNSIGNED32
1003h	**2**	2002	Standard error field 2	VAR	ro	UNSIGNED32
1003h	**3**	3003	Standard error field 3	VAR	ro	UNSIGNED32
1003h	**4**	4004	Standard error field 4	VAR	ro	UNSIGNED32

2.4.7. RECORD

A RECORD is a data type containing a variety of different entries/values. In some programming languages this data type is also referred to as a **structure**. In contrast to an *ARRAY*, in the case of a RECORD, the individual entries may consist of different data types. The value entries in a RECORD therefore have different meanings and contents, i.e. *Device code*. For the individual entries, the simple data types described above, such as *UNSIGNED32*, are used.

In the protocol described, the first entry of the RECORD defines the highest existing sub-index in the existing sections of a record. This entry always has a sub-index of 0 and is handled in a special way. The number of entries may be smaller than this value, as not all of the sub indexes need to be used. In a RECORD, a maximum of 255 entries are allowed.

The individual value entries are accessed via a sub-index. The first sub-index for a value entry is 1. If a sub-index is accessed which is of higher value than the content of the sub-index 0 (number of valid RECORD entries), an error message will occur. The same applies when accessing a "gap" in the RECORD (a non-defined sub-index).

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2.4.7.1. Example RECORD

The following example shows the structure of a RECORD in the OD.

See chapter *4.5°The Object Dictionary.*

Index	Sub	Value	Name	Type	Access	Data type
1018h			*Identity object*	RECORD		
1018h	**0**	4	Highest sub-index supported	VAR	const	UNSIGNED8
1018h	**1**	218	Vendor ID	VAR	ro	UNSIGNED32
1018h	**2**	928037	Product code	VAR	ro	UNSIGNED32
1018h	**3**	8	Revision number	VAR	ro	UNSIGNED32
1018h	**4**	4711	Serial number	VAR	ro	UNSIGNED32

2.4.7.2. Example RECORD with a "definition gap"

The following example shows the structure of a RECORD with a "gap" in the definition of the entries, see chapter *4.5.4.8 TPDO communication parameter*. In the example, the sub-index 4 is not defined and the number of the highest value sub-index = 5.

Index	Sub	Value	Name	Type	Access	Data type
1800h			*TPDO communication parameter 1*	RECORD		
1800h	**0**	***5***	Highest sub-index supported	VAR	const	UNSIGNED8
1800h	**1**	180h+ Node-ID	COB-ID	VAR	rw	UNSIGNED32
1800h	**2**	254	Transmission type	VAR	rw	UNSIGNED8
1800h	**3**	0	Inhibit time	VAR	rw	UNSIGNED16
1800h	***5***	1000	Event timer	VAR	rw	UNSIGNED16

2.4.8. STRING

A STRING is a particular data type used to visualise texts. A STRING consists of a variety of individual characters which generally represent one letter. In the memory, however, the individual characters are represented by a numeric value.

In the protocol described here, the STRING is represented by the data type VISIBLE_STRING.

The code, i.e. the relation between the letters and the numeric values in the memory, will be described in chapter *7.1 ASCII Table.*

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2.4.8.1. Example STRING

Representation of the STRING "**save**" and its assignment to the useful data bytes as part of a SDO command, see chapters *4.6.1 SDO* and ***Store parameters****.*

Byte 4	Byte 5	Byte 6	Byte 7
73h "s"	61h "a"	76h "v"	65h "e"

```
73h = 115d → s
61h =  97d → a
76h = 118d → v
65h = 101d → e
```

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3. Product interface

The actual communication characteristics of the measurement system will be explained in a more detailed way in the following. The structure of messages for the transmission of information, their functional context as well as their chronological sequence will be explained in a more detailed way in chapter *4 Protocol description CANopen.*

3.1. Quick guide

This chapter is designed to give the user quick answers to frequently occurring questions. For this purpose, the information is presented in the most compact way and provides cross-references to the related chapters for detailed information.

3.1.1. CANopen default settings

The signals in the measurement system which are typically pre-set for the process value transmission are explained below. Default settings depend on the model code and may deviate from the settings explained herein, particularly in devices with a modification (see user manual chapter "Model code"→ "Modification number"). The individual signal properties are described in chapter *3.3 Process data*

Range	Characteristic	Default settings
General Settings	*Baud rate*	*250 kbit/s*
	Node-ID	*1*
	Power ON Status	*Pre-Operational*
TPDO1	*Transmission Type*	254
	Event Timer	1000 ms
	Byte 0, 1	*Fluid temperature* *INTEGER16* 1 decimal for °C 1 decimal for °F
	Byte 2	*Status* *UNSIGNED8* *BITFIELD*

3.1.2. Device profile

ETS 4100 and ETS 4100S measurement systems support the CANopen device profile **CiA 404 "Device profile for measuring devices and closed-loop controllers".**

The exact measurement system-specific implementation of the device profile is described in chapter *3.5.3 Device profile-specific parameters*.

3.1.3. Important functions

Below please see a list of the most frequent changes to measurement systems required by users.

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3.1.3.1. Changing the device address (Node-ID)

In order to change the active device address, a particular order of actions has to be adhered to:

- **Set the device to network state "Pre-Operational"**
  - see chapter *4.4°Network Management*
  - "Enter pre-operational" see chapter *4.4.2 NMT*
- **Enter desired device address into Object 2003.2**
  - see object *Node* ID
  - see chapter *4.6.1°SDO*
- **Save changes to non-volatile device memory**
  - see description ***Store parameters***
  - see object ***Save LSS parameters***
- **Restart device**
  - see chapter *4.4°Network Management*
  - "Reset node" see chapter *4.4.2 NMT*
  - or cut device power supply and reactivate "power cycle"
- **Alternative option for changing the Node-ID**
  - see chapter *4.7°Layer setting services (LSS) Protocol*
  - see chapter *4.7.7°Example: setting the Node-ID and Baud rate via LSS*

CAN-Trace example change device address

The following example refers to a measurement system with an active device address 1 which is supposed to be changed to 10h (16d).

```
CAN-ID (hex)
|      Direction: Tx (ECU → Device); Rx (Device → ECU)
|      |  Data Length
|      |  |  Data Bytes (hex)
|      |  |  |
+---  +- +  +- -- -- -- -- -- -- --
NMT command "Enter Pre-Operational"
0000  Tx 2  80 01
Object 2003.2 „Set Pending Node-ID“ = 10h
0601  Tx 8  2F 03 20 02 10 00 00 00
0581  Rx 8  60 03 20 02 00 00 00 00
Object Function 1010.4 "StoreLSSParameter" ("save")
0601  Tx 8  23 10 10 04 73 61 76 65
0581  Rx 8  60 10 10 04 00 00 00 00
NMT command "Reset Node"
0000  Tx 2  81 01
→   Device reinitialisation in process
```

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```
"Boot-up" message with device address 10h
0710  Rx 1  00
```

3.1.3.2. Changing the Baud rate

In order to change the Baud rate, a certain order of actions has to be adhered to. This process is very similar to changing the Node-ID. Both changes may also be carried out simultaneously. For this purpose, the object of the Node-ID also has to be changed in the second step.

Please note: after the Baud rate has been changed, it is also necessary to change it in the consumer's messages.

Sequence of actions Baud rate:

- **Set the device to network state "Pre-Operational"**
  - see chapter *4.4°Network Management*
  - "Enter pre-operational" see chapter *4.4.2 NMT*
- **Enter desired Baud rate into Object 2004.2**
  - see object *Baud* rate
  - see chapter *4.6.1°SDO*
  - (option: additional change to Node-ID, see object *Node* ID)
- **Save changes to non-volatile device memory**
  - see description ***Store parameters***
  - see object ***Save LSS parameters***
- **Restart device**
  - see chapter *4.4°Network Management*
  - "Reset node" see chapter *4.4.2 NMT*
  - or cut device power supply and reactivate "power cycle"
- **Alternative option for changing the Baud rate**
  - see chapter *4.7°Layer setting services (LSS) Protocol*
  - see chapter *4.7.7°Example: setting the Node-ID and Baud rate via LSS*

CAN trace example change Baud rate

The following example refers to a measurement system with an active device address 1. The Baud rate is to be changed to 125 kbit/s.

```
CAN-ID (hex)
|      Direction: Tx (ECU → Device); Rx (Device → ECU)
|      |  Data Length
|      |  |  Data Bytes (hex)
|      |  |  |
+---   +- +  +- -- -- -- -- -- -- --
NMT command "Enter Pre-Operational"
```

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```
0000  Tx 2  80 01
```
Object 2004.2 "Set Pending Baudrate" = 4 (125 kbit/s)
```
0601  Tx 8  2F 04 20 02 04 00 00 00
0581  Rx 8  60 04 20 02 00 00 00 00
```
Object function 1010.4 "StoreLSSParameter" ("save")
```
0601  Tx 8  23 10 10 04 73 61 76 65
0581  Rx 8  60 10 10 04 00 00 00 00
```
NMT command "Reset Node"
```
0000  Tx 2  81 01
→   Device reinitialisation in process
```

"*Boot-up*" message with device address 1h
```
0701  Rx 1  00
```

3.1.3.3. Save settings

In order to save configurations in the measurement system permanently, the *"Store" functions* should be explicitly activated after having changed the parameter. These functions are explained in chapter *4.5.4.3 Storage and restoring (general communication objects)*.

3.1.3.4. Reset to default settings

Reset to default settings is performed via "*Loading and storage parameters*" from the OD range *4.5.4 Communication profile area*.

Inquiry of function parameters "*Restore default parameters"* all parameters will be loaded (except the settings for Node-ID and Baud rate). In order to make the settings apply, the device has to be reset; see chapter*4.4.2 NMT*.

3.1.3.5. Changing the transmission type for process data

The related communication parameters of the PDO define how and when the process data is transmitted.

For **RPDO -** Process data received by the measurement system

- *4.5.4.6 RPDO communication parameter*
- *4.6.2.1 Event driven*
- *4.6.2.2 SYNC*
- *4.6.2.4 Overview diagram PDO mapping*

For **TPDO -** Process data sent by the measurement system

- *4.5.4.8 TPDO communication parameter*
- *4.6.2.1 Event driven*
- *4.6.2.2 SYNC*
- *4.6.2.4 Overview diagram PDO mapping*

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3.1.3.6. Changing the content of the process data

The content of the process data is administrated via the "PDO Mapping" see chapter *4.6.2.3 PDO Mapping* and *4.6.2.4 Overview diagram PDO mapping*.

To change the mapping, a defined process has to be adhered to, see chapter *4.6.2.5 Process flow sequence to change the "PDO mapping"*.

3.1.4. What to do if no process data has been recognised

As CANopen offers high flexibility, unfortunately there are also many different causes for measurement system process data not being transmitted or received. In the following, a few points are listed which should be checked if no data or no plausible data is being transmitted.

- **Network state "Pre-Operational"**

  A measurement system in the "**Pre-Operation"** state does not send **any** process data, see chapter *4.4.1 Overview of network states*.

  The current network state can be read out from the "Heartbeat" protocol's data while this is active, see chapter *4.4.3 Heartbeat*.

- **SYNC based PDO communication**

  If, for the transmission of a PDO the SYNC service is active, the measurement system will either **send** a PDO only **after receiving** one or several **SYNC messages** or further process a received signal. No PDO will be exchanged without any SYNC messages.

  Further information on how the SYNC processing is carried out and how it is activated is explained in the following chapters:

  4.6.2.2 SYNC

  4.5.4.8 TPDO communication parameter.

- **PDO COB-ID/CAN-ID parameter settings**

  Via which CAN-ID a PDO will be transmitted is defined by the PDO's COB-ID. The parameters for this will be explained in the following chapters: for RPDO → 4.5.4.6and for TPDO → 4.5.4.8.

  The configuration options at the COB-ID decide if a PDO will be sent at all and if the producer and the consumer work with the same ID.

  - **PDO transmission active**

    The identifier "invalid" in the COB-ID (bit 31) of a PDO decides whether a PDO is sent/received at all, see object *TPDO.COB-ID*.

  - **CAN-ID correctly evaluated**

    The PDO's CAN-ID is usually calculated from the current Basis CAN-ID and the current *Node-ID*of the measurement system, see object *TPDO.COB-ID*.

    It can easily happen that the receiver is still configured to respond to the "old" CAN ID, despite having changed the Node-ID of the measurement system. It may therefore occur that messages sent via the "new" CAN ID are ignored by the PDO.

- **Evaluation of process data**

  The correct evaluation of the process data is slightly more complicated. When it has been ensured that the desired PDO has been received, the desired *Process value* has to be copied from the *CAN data block* and needs to be interpreted correctly.

  If the measurement system in question still has its factory default settings, the presetting of the process data is described in chapter *3.1.1 CANopen default* settings*.*

  If the measurement system already has an individual configuration, the mechanisms described in chapter *4.6.2 PDO* will apply. Chapter *4.6.2.4 Overview diagram PDO mapping* provides a good overview for this purpose.

3.2. Product description

ETS 4100 / ETS 4100S CANopen are digital temperature transmitters for the detection of the fluid temperature in hydraulic applications. The new generation of smart sensors (ETS 4100S) provides further interesting information in addition to the regular process data, as a history backup of operation conditions for example.

With the temperature sensor, based on a PT 1000 and corresponding evaluation electronics, fluid temperatures ranging from -25 °C to +100 °C can be measured. Due to a pressure resistance of 600 bar and excellent EMC characteristics, the ETS 4100(Smart) is ideal for use in harsh conditions.

> The following please find the most important information on this product. The information listed herein is non-formal and is provided solely for the purpose of helping readers to understand the context. A more detailed description of the product properties is available in the associated operating manual.
>
> In case of doubt, the information given in the operating manual always applies.

3.2.1. Fluid temperature measurement

The ETS 4100 and ETS 4100S pressure transmitters provide their nominal measured variable "fluid temperature measurement" as a process value.

- *3.3.2 Signal "fluid temperature"*

3.2.2. Additional Signal Device Temperature

In addition to the process value "fluid temperature", the ETS 4100 and ETS 4100S measurement systems provide the signal of "device temperature".

- *3.5.5.1 "Device temperature" signal*

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3.2.3. Recording of additional operating data "smart functions"

The ETS 4100S measurement systems even provide further signals on top of the fluid temperature measurement and the device temperature. These signals can be used not only for the optimisation of control functions, but also for tasks in predictive maintenance or for error diagnostics.

As a result, this measurement system series provides a high variety of device information and diagnostic data, ranging from measurement channel-related events, such as general operating hours, event counters or statistics for the actual operation range of the measurement system inside of the machine, through to operating hours per measuring range segment, measurement overruns or underruns or overload events.

- Smart functions "operating hours"
- Smart functions "switching channels" and "counters"
- Smart functions "device temperature values"
- Smart functions "operating data"

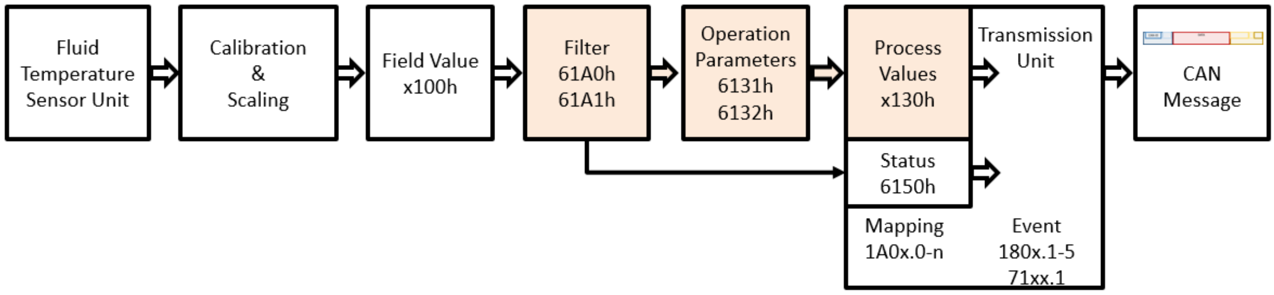
3.3. Process data

Further information on the meaning or the parameterisation of process data can be found in chapter *4.6.2 PDO.*

3.3.1. Measured data processing

All signals provided by the measurement system are processed in the same way. The important measurands for the evaluation and conversion of the signal are listed in a table.

Below flow diagram represents the way of measured data processing



- Sensor Unit

  The sensor unit reports the raw values of the sensor cell which is relevant for the signal as a sensor value and makes it available for further signal processing.

- Calibration & Scaling

  This signal step performs the error correction, the scaling as well as the zero-point correction. The corrected sensor signal values are now available as "Field Value".

- Filter

  On this signal level, the processed signal values are now converted and filtered to become the relevant process signal.

- Transmission Unit

  If one of the following events occurs, the value of the *PDO* is sent or received and processed depending on the preset *Transmission Type*.

  1. The *Event Timer* has expired (cyclical transmission).
  2. One or more *SYNC objects* have been received (synchronous transmission).
  3. Profile-specific events

The cross-references are indicated as shown below:

Signal description Reference to the chapter which gives a short explanation of the characteristics of the relevant signal. A more detailed description can be found in the related operating manual.

Signal characteristics Refers to the chapter describing the characteristics necessary for evaluation, e.g. evaluation of the measuring range.

Status information Refers to the chapter which explains the exact structure of a status value belonging to a signal (mainly a BITFIELD).

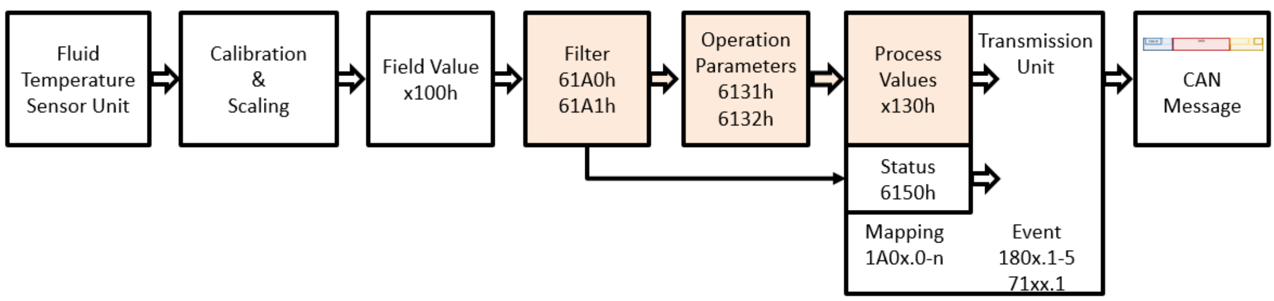
The following table explains the meaning of the individual signal properties of a signal description.

Signal properties	**Description**
Measuring range min.	The smallest physical value displayable by the signal.
Measuring range max.	The greatest physical value displayable by the signal.
Resolution	The physical value of an individual bit of the numeric value. Definition of the conversion between the numeric value of the data type and the physical size of the signal. Example: Numerical value: 4711d Resolution: 0.01 °/bit 4711d * 0.01 °/Bit = 47.11 °

Signal properties	Description
Offset	Any zero offset of the numeric value. An offset is mainly used if the data type of the transmitted numeric value is unsigned. Example: Numerical value: 61d measuring range: -40 to +210 °C Resolution: 1 °C/bit Offset: -40 °C (61d * 1 °C/Bit) + (-40 °C) = 21 °C
Data type	Data type of the numeric signal value during transmission, see chapter *2.4 Data* types and *2.3 Bit order*.
Data length	Length of the data type used for the transmission in bits.
Mappable	Defines if and which way the signal can be transmitted via CANopen *Process data object*. TPDO, RPDO or SRDO.
Process value index	Index number of the object with the current process value for the visualisation on a PDO. Example: 7130.[1] *Fluid Temperature value*
Default settings	Describes if and via which *Process data object*the signal will be transmitted during emission: TPDO, RPDO or SRDO.

3.3.2. Signal "fluid temperature"

Both product families (ETS 4100 and ETS 4100S) emit the signal for "fluid temperature". This signal meets the requirements of the device profile CiA 404.

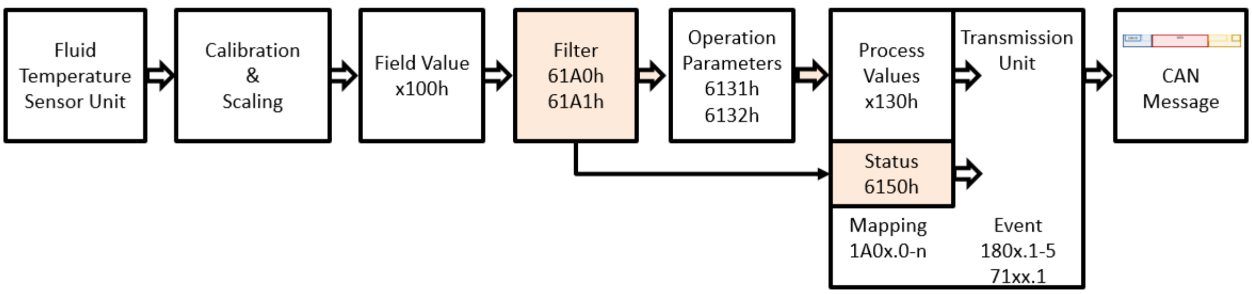


Signal description *3.2.1 Fluid temperature measurement*
Status information *3.3.3 Status "Fluid temperature"*

Signal properties	Value	Additional information
measuring range min.	e.g. -25 e.g. -13	[°C] depending on the model [°F] depending on the model
Measuring range max.	e.g. 100 e.g. 212	[°C] depending on the model (-25 .. 100) [°F] depending on the model (-13 .. 212)
Resolution	1 1	Number of decimals for °C Number of decimals for °F
Offset	0	[°C] / [°F] depending on the model
Data type	***INTEGER16*** *REAL32* *INTEGER32*	Signed integer Floating point number Signed integer
Data length	**16**/32	Dependent on the data type used
Mappable	*TPDO*	
Process value index	**7130.0** 6130.0 9130.0	*Fluid temperature* INTEGER16 *Fluid temperature* REAL32 *Fluid temperature* INTEGER32
Default settings	TPDO1	Byte 0, 1 Fluid temperature

3.3.3. Status "Fluid temperature"

The status of the signal "fluid temperature" gives information on the validity of this signal. The status is structured as a bit field. For the intended use of the measurement system, the "fluid temperature" status should always be evaluated in combination with the "fluid temperature" process value signal (see operating instructions).



Signal properties	Value	Additional information
measuring range min.	-	*BITFIELD*; Bit value 0/FALSE/inactive
measuring range max.	-	*BITFIELD*; Bit value /TRUE/active
Resolution	-	
Offset	-	

Signal properties	Value	Additional information
Data type	*UNSIGNED8*	*BITFIELD see chapter 3.3.3.1*
Data length	8	Bit
Mappable	*TPDO*	
Process value index	**6150.0**	*Fluid temperature status*
Default settings	TPDO1	Byte 2

3.3.3.1. Design of the BITFIELD status "fluid temperature"

In the following, the meaning of the individual identifiers in a BITFIELD are described.

Bit	Meaning
0	**Not valid**
1	**Positive overload over 100%**
2	**Negative overload**
3	Reserved
4	Reserved
5	Reserved
6	Reserved
7	Reserved

3.3.4. Additional signals

This measurement system used provides additional signals in the form of additional measurement channels in addition to its nominal measured variable. However, these signals do not map any process data in the conventional sense. These signals are auxiliary measured variables, which are not part of the data sheet.

Signal description *3.5.5.1 "Device temperature" signal*

3.4. Functionally safe process data

The measurement systems described in this documentation (see chapter *1.1 Scope* of application) do not support functionally safe communication.

3.5. Parameters

In CANopen applications, parameters are to be equating to the objects of the "object dictionary". All parameters of the measurement system are therefore represented in the OD (see chapter *4.5 The Object* Dictionary).

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The parameters described in this chapter are additional device-specific parameters or device profile-specific parameters or parameters whose behaviour deviates from the general protocol description.

3.5.1. Configuration parameters

This chapter will explain all configuration parameters specific to this measurement system. The following description will expand on or replace the listed parameter descriptions in the general protocol description, see chapter *4.5.4 Communication profile area*.

Parameters for the visualisation and management of errors will be explained separately in an extra chapter *3.7.3 General error* management.

Name	Index	Sub	Type	Acc	PDO
RPDO communication parameter 1	**1400h**		*RECORD*		
This object is **not supported** by ETS 4100 and ETS 4100S.					
RPDO mapping parameter 1	**1600h**		*RECORD*		
This object is **not supported** by ETS 4100 and ETS 4100S.					

3.5.2. Manufacturer-specific configuration parameters

This chapter will explain all customer-specific configuration parameters of this measurement system. The following description will expand on or replace the listed parameter descriptions in the general protocol description.

This range of parameter is used in different forms in the measurement system. The management of the Node-ID and baud rate, the storage of default settings for the DS 404 process value configuration as well as the management of additional values of our measurement systems with "smart" functions - the operating statistics.

The generally applicable manufacturer-specific parameters can be found in chapter *4.5.5 Manufacturer-specific profile area*.

3.5.2.1. Management of Node-ID and baud rate

The measurement systems of the ETS 4100 and ETS 4100S series offer, in addition to LSS, two methods for managing the Node-ID. For reasons of compatibility to our predecessor products, the objects 2001h and 2002h are still available. In addition, the currently standard process used at HYDAC Electronic is made available via the objects 2003h and 2004h. See chapter *4.5.5.1 Node-ID and Baud rate*.

Both processes are synchronised with each other so that changes after one of the two processes are copied to the objects of the respective other process.

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Name	Index	Sub	Type	Acc	PDO
Node-ID (Procedure 1)	**2001h**		*UNSIGNED32*	rw	

To change the Node-ID, this must be written into the object together with the character string "set". After the change is made, this must be permanently saved, see *StoreLSSParameter* and the measurement system must be restarted.

Example: setting the Node-ID 5h via "*SDO download*"

Byte 4	Byte 5	Byte 6	Byte 7
<data> Node-ID	<data> "s"	<data> "e"	<data> "t"
05h	73h	65h	74h

Name	Index	Sub	Type	Acc	PDO
Baudrate (Procedure 1)	**2002h**		*UNSIGNED32*	rw	

Procedure 1 for Baudrate

To change the Node-ID, this must be written into the object together with the character string "set". After the change is made, this must be permanently saved, see *StoreLSSParameter* and the measurement system must be restarted.

Example: setting the *Baudrate 125 bit/s* (Index 4h) via "*SDO download*"

Byte 4	Byte 5	Byte 6	Byte 7
<data> Baudrate	<data> "s"	<data> "e"	<data> "t"
04h	73h	65h	74h

Name	Index	Sub	Type	Acc	PDO
Node-ID (Procedure 2)	**2003h**		*ARRAY*		
Active node-ID		01	*UNSIGNED8*	ro	
Pending node-ID		02	*UNSIGNED8*	rw	

Current process for changing the Node-ID. See chapter *4.5.5.1 Node-ID and Baud* rate.

Name	Index	Sub	Type	Acc	PDO
Baudrate (Procedure 2)	**2004h**		*ARRAY*		
Active baudrate		01	*UNSIGNED16*	ro	
Pending baudrate		02	*UNSIGNED16*	rw	

Current process for changing the baud rate , see chapter *4.5.5.1 Node-ID and Baud* rate.

3.5.2.2. Default for the factory settings for DS 404 process value configuration

The device provides the plant-side default of the parameters to configure the "fluid temperature" process value in the index range 21xxh. These values are copied into the object entries 6xxxh, 7xxxh and 9xxxh when resetting the measurement system to default settings. See chapter *4.5.4.3 Storage and restoring (general communication objects).*

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Name	Index	Sub	Type	Acc	PDO
AI default input scaling 1 PV	**2121h**		*ARRAY*		
AI default input scaling 1 PV 1		01	*INTEGER32*	ro	
Default setting; lower value for scaling the process value for the "fluid temperature" signal. Default for the object entries 6121h, 7121h, 9121h when calling up the function "*Restore default parameters*".					
AI default input scaling 2 PV	**2123h**		*ARRAY*		
AI default input scaling 2 PV 1		01	*INTEGER32*	Ro	
Default setting; upper value for scaling the process value for the "fluid temperature" signal. Default for the object entries 6123h, 7123h, 9123h when calling up the function "*Restore default parameters*".					
AI default physical unit PV	**2131h**		*ARRAY*		
AI default physical unit PV 1		01	*UNSIGNED32*	Ro	
Factory settings; physical unit for the "fluid temperature" signal Default for the object input 6131h when calling up the function "*Restore default parameters*".					
AI default decimal digits PV	**2132h**		*ARRAY*		
AI default decimal digits PV 1		01	*UNSIGNED8*	ro	
Factory settings; number of decimal places of the "fluid temperature" signal Default for the object input 6132h when calling up the function "*Restore default parameters*".					
Limitation FV	**2300h**		*ARRAY*		
AI Limitation FV 1		01	*UNSIGNED8*	rw	
Limitation of the "fluid temperature" field value. The limitation serves to avoid measured values below the lower measuring range limit due to tolerances, long-term drift, cavitation and similar effects. Value: 0 no limitation 1 the field value and process value derived from this is limited to the lower measuring range limit					

3.5.2.3. Parameter for smart function "operating hours"

The ETS 4100S provides its operating hours (active operating period).

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Name	Index	Sub	Type	Acc	PDO
Lifetime operating hours	**4100h**	01	*UNSIGNED32*	ro	
Operating hours of the sensor					
Lifetime device arrhenius	**4100h**	02	*UNSIGNED32*	ro	
Fluid temperature-weighted operation hours (= Arrhenius)					
Lifetime fluid arrhenius	**4100h**	03	*UNSIGNED32*	ro	
Fluid temperature-weighted operation hours (= Arrhenius)					
Resettable operating hours	**4101h**	01	*UNSIGNED32*	ro	
The resettable operating hours can be set back via the Index 41A0.01h (Reset Operating Time).					
Resettable fluid arrhenius	**4101h**	02	*UNSIGNED32*	ro	
The resettable Arrhenius of the fluid can be reset via Index 41A0.02h (Reset Operating Time).					

3.5.2.4. Parameters for smart functions "switching channels" and "counters"

The device ETS 4100S provides two switching signal channels SSCs, which are configurable by the customer, i.e. there are two set points per SSC which can be set (example: set point 1 = 60 °C and set point 2 = 100 °C). The counter determines how often the sensor has been inside of this range.

Configuration of SSC1 and SSC2:

- ***Logic: Switching logic: Default: High active***

High Active means:

SSC = 0 = OFF

SSC = 1 = ON

Low Active means:

SSC = 0 = ON

SSC = 1 = OFF

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- ***Mode: Switching function*** – Default: Deactivated

  - Deactivated: The SSC is always OFF

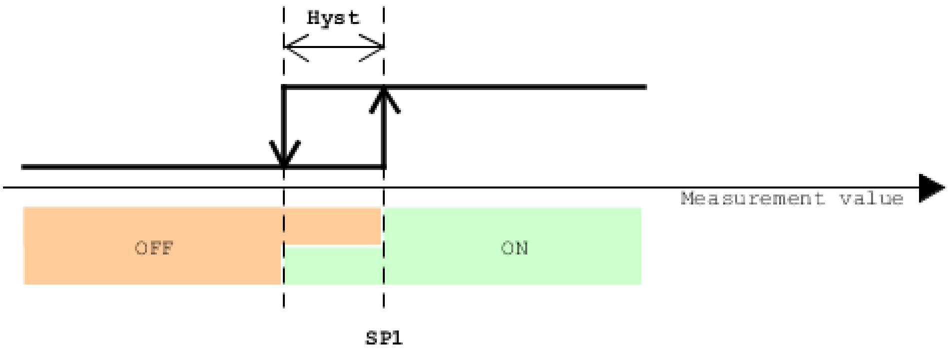
  - Single-Point / Hysteresis

In the single point mode the parameters SP1 and Hyst are used.

If the measured value reaches or exceeds the switching point SP1, the SSC will switch ON.

If the measured value falls below the switch back point SP1 - Hyst,

the SSC will switch OFF.



SSC → ON, if measured value ≥ SP1

SSC → OFF, if measured value < SP1 - Hyst

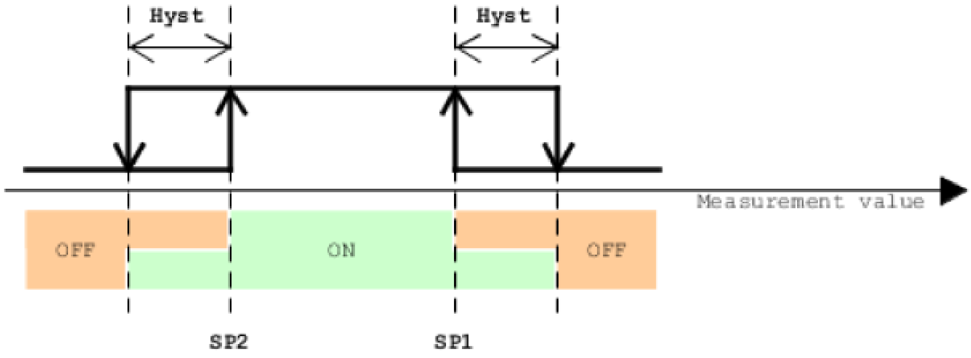
  - Window / Hysteresis

In the window mode the parameters SP1, SP2 and Hysteresis are used.

If the measured value stays within the window [SP2, SP1], the SSC will switch to ON.

If the measured value falls below the lower window frame SP2 – Hyst, the SSC will switch to OFF.

If the measured value rises over the upper window frame SP1 + Hyst, the SSC will switch to OFF.



SSC → ON, if SP2 ≥ measured value ≥ SP1

SSC → OFF, if measured value < SP2 - Hyst or measured value > SP1 + Hyst

- Two point mode

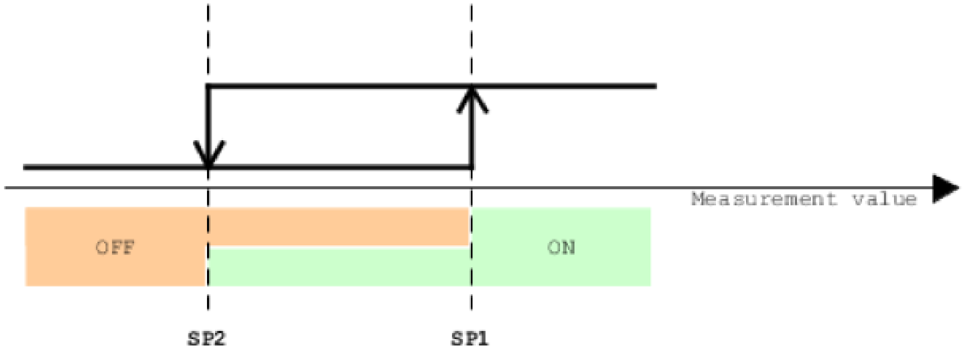
In the two-point mode the parameters SP1 and SP2 are used.

If the measured value reaches or exceeds the switching point SP1, the SSC will switch to ON.

the SSC will switch ON.

SSC OFF.

SSC OFF.



SSC → ON, if measured value ≥ SP1

SSC → OFF, if measured value < SP2

- Hysteresis

Hysteresis in bar, amount of decimal places depending on the measuring range.

The Hysteresis is used in the modes "Single-Point" and "Window"

(see above).

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Name	Index	Sub	Type	Acc	PDO
SSC 1.1 **SSC 1.2**	**4040h** **4041h**		*RECORD*		
Switching Signal Channel 1.x = Switching Signal Channel 1, Signal x					
State (SSC Status)	**404xh**	01	*UNSIGNED8*	ro	
0 = Configuration valid 1 = Configuration not valid					
Setpoint 1 (SP1)		02	*INTEGER32*	rw	
Setpoint 2 (SP2)		03	*INTEGER32*	rw	
Logic		04	*UNSIGNED8*	rw	
0 = Switching logic High Active 1 = Switching logic Low Active					
Mode		05	*UNSIGNED8*	rw	
0 = Switching function deactivated 1 = Switching function Single Point 2 = Switching function Window 3 = Switching function Two Point					
Hysteresis		06	*INTEGER32*	rw	
Lifetime channel 1	**4110h**		*RECORD*		
Average value		01	*INTEGER32*	ro	
Min value		02	*INTEGER32*	ro	
Max value		03	*INTEGER32*	ro	
The channel-related lifelong values					
Resettable channel 1	**4111h**		*RECORD*		
Average value		01	*INTEGER32*	ro	
Min value		02	*INTEGER32*	ro	
Max value		03	*INTEGER32*	ro	
The channel-related resettable values The resettable values can be reset via the Index 41A0.02h (Reset Channel Operating Data).					
Lifetime counter channel 1	**4112h**		*RECORD*		
Underrun count		01	*UNSIGNED32*	ro	

Overflow count		02	*UNSIGNED32*	ro
Overload count		03	*UNSIGNED32*	ro
Measurement error count		04	*UNSIGNED32*	ro
The channel-related counted values				
Resetable counter channel 1	**4113h**		*RECORD*	
SSC 1.1 count		01	*UNSIGNED32*	ro
SSC 1.2 count		02	*UNSIGNED32*	ro
The channel-related resettable counted values The resettable values can be reset via the Index 41A0.02h (Reset Channel Operating Data).				
Lifetime statistic channel 1	**4114h**		*RECORD*	
Operating time 1		01	*UNSIGNED32*	ro
Operating time …		…	*UNSIGNED32*	ro
Operating time 11		0B	*UNSIGNED32*	ro
Channel-related lifelong statistics It is defined for each product if and how many statistical values are used, and what the used statistical values stand for. Size and order of the range segments depends on the measurement variable and the measuring range. For details, please see entry in the relevant EDS file. In total, there are up to 11 default set ranges possible in the factory settings.				

3.5.2.5. Parameters for smart function "device temperature"

The ETS 4100S provides its device temperature which has been measured inside of the sensor.

Name	Index	Sub	Type	Acc	PDO
Lifetime device temperature	**4188h**		*RECORD*		
Average value		01	*INTEGER32*	ro	
Min value		02	*INTEGER32*	rw	
Max value		03	*INTEGER32*	rw	
Device temperature values					

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Resetable device temperature	**4189h**		*RECORD*	
Average value		01	*INTEGER32*	ro
Min value		02	*INTEGER32*	ro
Max value		03	*INTEGER32*	ro
Erasable device temperature values				
Lifetime counter device temperature	**418Ah**		*RECORD*	
Underrun count		01	*UNSIGNED32*	ro
Overflow count		02	*UNSIGNED32*	ro
Measurement error count		04	*UNSIGNED32*	ro
Lifetime statistic device temperature				
Lifetime statistic device temperature	**418Ch**		*RECORD*	
Operating time 1		01	*UNSIGNED32*	ro
Operating time …		…	*UNSIGNED32*	ro
Operating time 7		07	*UNSIGNED32*	ro

It is defined for each product if and how many statistical values are used, and what the used statistical values stand for.

Size and order of the range segments depends on the measurement variable and the measuring range.
Details see entry in the relevant EDS file.

Example:
Typically used default settings

- 20 % FS increments
- 1 range below 0 % FS
- 5 ranges of 0 % FS .. 100 % FS
- In the case of temperature, up to 2 ranges above 100 % FS

Operating time 1 in the range of < 0 %	< -25 °C
Operating time 2 in the range of 0 .. 20 %	-25 .. 0 °C
Operating time 3 in the range of 20 .. 40 %	0 .. 25 °C
Operating time 4 in the range of 40 .. 60 %	25 .. 50 °C
Operating time 5 in the range of 60 .. 80 %	50 .. 75 °C
Operating time 6 in the range of 80 .. 100 %	75 .. 100 °C
Operating time 7 in the range of 100 .. 120 %	100 .. 125 °C
Operating time 8 in the range of 120 .. 140 %	125 .. 150 °C

3.5.2.6. Parameters for smart function "reset operating data"

In this object, all general data in the ETS 4100S can be set back.

Name	Index	Sub	Type	Acc	PDO
Reset operating data	**41A0h**		*ARRAY*		
Reset common operating data		01	*UNSIGNED32*	wo	
Erasing the general operating data (i.e. operating hours) In order to set back the general operating data, the signature 0x72657300 (corresponds with the character string "res/0") has to be set via the Index 41A0.02h (Reset Channel Operating Data).					
Reset channel operating data	**41A0h**	02	*UNSIGNED32*	wo	
Erasing the channel-related operating data					

3.5.3. Device profile-specific parameters

ETS 4100 and ETS 4100S measurement systems support the device profile "CiA 404 Device profile for measuring devices and closed-loop controllers".

The process data transmitted when the device is reset to factory settings is described in chapter *3.1.1 CANopen default* settings.

Certain objects have a generally applicable and device profile-specific section. These objects (for example the object *Error* behaviour) only describe the section which is defined via the device profile. The definitions which are generally applicable are described in chapter *4.5.4 Communication profile area*.

> The objects from the device profile CiA 404 "Device profile for measurement devices and closed-loop controllers" which are not listed below are not supported by the measurement system.

The device profile documentation version, which serves as a basis for the implementation of the measurement system, can be taken from the operating manual.

Name	Index	Sub	Type	Acc	PDO
Device Type	**1000h**	0	*UNSIGNED32*	ro	
Bit 0-15 contains the device profile 019Ah → CiA 404 Bit 16-31 contains profile-specific information 0002h→ Analogue input					
Error register	**1001h**	0	*UNSIGNED8*	ro	TP
Device error status. This error status is also part of the EMCY message, see chapter *4.4.5*					

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Name	Index	Sub	Type	Acc	PDO
EMCY. Bit 0 Generic error Bit 4 Communication error Bit 7 Manufacturer specific As soon as a communication error or manufacturer-specific error has occurred, the generic error is set.					
Error behaviour	**1029h**		*ARRAY*		
For general information, see chapter *4.5.4.1 Error management (General communication* objects).					
Communication error	**1029h**	1	*UNSIGNED8*	rw	
Device behaviour in case a communication error occurs.					
Analog input error	**1029h**	3	*UNSIGNED8*	rw	
"Error behaviour "Analogue input error"; Error behaviour in case of an internal device error. Description of the error behaviour. See chapter *4.5.4.1* Error management (General communication objects) Object: *Error behaviour*					

The device profile-specific parameters are described in the following table: The individual parameters are stored in the form of an ARRAY (see chapter *2.4.6 ARRAY*). In this context, sub-index 0 always represents the amount of measured values provided by the measurement system. sub-index 1 to "n" provides the parameter written onto by the object for the specific measurement channel.

In the current case of ETS 4100 / ETS 4100S only one sub-index 1 will be mapped (for the "fluid temperature" signal).

Name	Index	Sub	Type	Acc	PDO
AI input FV	**6100h**	1	REAL32	ro	TP
	7100h	1	INTEGER16	ro	TP
	9100h	1	INTEGER32	ro	TP
The device provides the current field value *Analogue Input Field Value 1*. 0 % = 0; 100 % = 5000 This object provides the converted value of an analogue input, which is not yet scaled to the physical unit of the measured variable.					
AI Sensor Type	**6110h**	1	UNSIGNED16	ro	
0x64 = 100 = Sensor type temperature					
AI autocalibration	**6111h**	1	UNSIGNED32	wo	

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Name	Index	Sub	Type	Acc	PDO
(not provided for "fluid temperature")					
AI operating mode	**6112h**	1	UNSIGNED8	const	
1 = Normal Operation					
AI ADC sample rate	**6114h**	1	UNSIGNED32	rw	
Sampling rate in microseconds: 0x3e8 = 1000 The sampling rate determines the interval at which a new measured value is processed. This time has an impact, especially in connection with the filter constant and the trigger handling.					
AI input scaling 1 FV	**6120h**	1	REAL32	ro	
	7120h	1	INTEGER16	ro	
	9120h	1	INTEGER32	ro	
Lower value of the field value. This is used to scale the "fluid temperature" process value. Value: 0					
AI input scaling 1 PV	**6121h**	1	REAL32	rw	
	7121h	1	INTEGER16	rw	
	9121h	1	INTEGER32	rw	
Lower value for scaling the process value "fluid temperature" value: e.g. -25 = for sensor with a measuring range up to -25 °C.					
AI input scaling 2 FV	**6122h**	1	REAL32	ro	
	7122h	1	INTEGER16	ro	
	9122h	1	INTEGER32	ro	
Upper value of the field value. This is used to scale the "fluid temperature" process value. Value: 5000					
AI input scaling 2 PV	**6123h**	1	REAL32	rw	
	7123h	1	INTEGER16	rw	
	9123h	1	INTEGER32	rw	
Upper value for scaling the process value "fluid temperature" value: e.g. 100 = for sensor with a measuring range up to 100 °C					
AI input offset	**6124h**	1	REAL32	rw	
	7124h	1	INTEGER16	rw	
	9124h	1	INTEGER32	rw	
Offset for scaling 0					
AI autozero	**6125h**	1	UNSIGNED32	wo	

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Name	Index	Sub	Type	Acc	PDO
	7125h	1	UNSIGNED32	wo	

Sets the offset so that the PV (process value) results in 0 (relative output)
write 0x6f72657a

Name	Index	Sub	Type	Acc	PDO
AI input PV	**6130h**	1	UNSIGNED32	ro	TP
	7130h	1	INTEGER16	ro	TP
	9130h	1	INTEGER32	ro	TP

Current process value "fluid temperature" [°C] / [°F] – depending on the model
Signal description *3.2.1 Fluid temperature measurement*
Signal characteristics *3.3.2 Signal "fluid temperature"*
Status characteristics *3.3.3 Status "Fluid temperature"*

Name	Index	Sub	Type	Acc	PDO
AI physical unit PV	**6131h**	1	UNSIGNED32	rw	

Physical unit of the process value

0x002d000 = 2949120 = °C
0xac0000 = 11272192 = °F

Name	Index	Sub	Type	Acc	PDO
AI decimal digits PV	**6132h**	1	UNSIGNED8	rw	

Decimal places

The transferred integer value 1234 with 2 decimal places means 12.34.
This applies to all 16 bit and 32 bit signed integers, such as: (indices 71xxh, 91xxh)

Example: Sensor sends -250 to 1000 digits. Decimal places = 1 means -25 to 100 °C
If you convert to 2 decimal places, you get - 2.5 .. 10.0 °C.
If you then change 6123h (AI Scaling 2 PV 1) from 1000 to 10000, you get -2.5 .. 100 °C!

Name	Index	Sub	Type	Acc	PDO
AI interrupt delta input PV	**6133h**	1	REAL	rw	
	7133h	1	INTEGER16	rw	
	9133h	1	INTEGER32	rw	

This entry is used to control the *PDO* transmission.
If the current *ProcessValue* deviates from the last one transmitted by more than the *InterruptDeltaPV*, it will be transmitted. This prevents constant transmissions where the contents are very similar. So that this mechanism is activated, *TransmissionType* must be set to *ProfileSpecific.* See chapter *3.6.3 Device-specific PDO events*
If *InterruptDeltaPV* is set to 0, then this mechanism is deactivated.

Name	Index	Sub	Type	Acc	PDO
AI interrupt lower limit input PV	**6134h**	1	REAL32	rw	
	7134h	1	INTEGER16	rw	
	9134h	1	INTEGER32	rw	

This entry serves to control the PDO transmission

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Name	Index	Sub	Type	Acc	PDO
If the current *ProcessValue* falls below the *InterruptLowerLimit* limit value, it will be transmitted. In order to avoid constant transmissions because the measured value is fluctuating around the limit value, the actual value must rise above the limit again by at least 1% of the preset measuring range, before another transmission is made for a fall in value. In order for this mechanism to be activated, *TransmissionType* must be set to *ProfileSpecific, s*ee chapter *3.6.3 Device-specific PDO events*					
AI interrupt upper limit input PV	**6135h**	1	REAL32	rw	
	7135h	1	INTEGER16	rw	
	9135h	1	INTEGER32	rw	
This entry serves to control the PDO transmission If the current *ProcessValue* exceeds the *InterruptUpperLimit* limit value, it will be transmitted. In order to avoid constant transmissions because the measured value is fluctuating around the limit value, the actual value must exceed the limit again by at least 1% of the preset measuring range, before another transmission is made for this event. In order for this mechanism to be activated, *TransmissionType* must be set to *ProfileSpecific, s*ee chapter *3.6.3 Device-specific PDO events*					
AI interrupt hysteresis input PV 1	**6136h**	1	REAL32	rw	
	7136h	1	INTEGER16	rw	
	9136h	1	INTEGER32	rw	
Hysteresis to lower and upper value fluid temperature Default: always 1% of the upper limit for fluid temperature (e.g. 1.00 for the sensor with 100 °C)					
AI span start	**6148h**	1	REAL32	rw	
	7138h	1	INTEGER16	rw	
	9138h	1	INTEGER32	rw	
Default: -25 (sensor lower limit) This value is adjustable. If the current *ProcessValue* falls below the limit value, a bit is set in the status, see chapter *3.3.3.1 Design of the BITFIELD status "fluid temperature"*.					
AI span end	**6149h**	1	REAL32	rw	
	7139h	1	INTEGER16	rw	
	9139h	1	INTEGER32	rw	
Default: fluid temperature sensor upper limit (e.g. 100 for the sensor with 100 °C) This value is adjustable. If the current *ProcessValue* exceeds the limit value, a bit is set in the status, see chapter *3.3.3.1 Design of the BITFIELD status "fluid temperature"*.					

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Name	Index	Sub	Type	Acc	PDO
AI status	**6150h**	1	UNSIGNED8	ro	TP
See chapter *3.3.3 Status "Fluid temperature"*					
AI filter type	**61A0h**	1	UNSIGNED8	rw	
Filter type Default value 0 = no filter; 1 = Moving average (low pass filter); 2 = Repeating average (arithmetic average)					
AI filter constant	**61A1h**	1	UNSIGNED16	rw	
Filter constant					

3.5.4. Process value parameters

Process value parameters either contain the current process values themselves or serve to configure the process values. The configuration can affect the representation of the numeric values or the number of decimals during transmission.

For the transmission of the process value, the actual process value parameter which contains the desired current process value can be projected onto a PDO, see chapters *4.6.2 PDO* and *4.5.1.4 Objects serving* as *process data content.*

3.5.4.1. Number of the process data objects supported by the device.

- **TPDO** "sent process data" **1**
- **RPDO** "received process data" **0**

3.5.4.2. Description of process value parameters

All process parameters are described in the chapters *3.5.3* Device profile-specific *parameters* or in the *device profile CiA 404*.

3.5.5. Additional manufacturer-specific measurement channels

The ETS 4100 and ETS 4100S temperature transmitters provide an additional measurement channel.

3.5.5.1. "Device temperature" signal

The device detects a "device temperature" signal in addition to its measured real fluid temperature value.

Signal properties	Value	Additional information
Measuring range min.	e.g. -25 e.g. -13	[°C] for sensors with a °C variant [°F] for sensors with a °F variant
measuring range max.	e.g. 100 e.g. 212	[°C] for sensors with a °C variant [°F] for sensors with a °F variant

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Signal properties	Value	Additional information
Resolution	1	[°C/Bit] or [°F/Bit]
Offset	0	[°C] or [°F]
Data type	*REAL32*	Floating point
Data length	32	Bit
Mappable	*TPDO*	ro
Process value index	**3610.1** 3710.1 3910.1	*Device temperature* REAL32 *Device temperature* INTEGER16 *Device temperature* INTEGER32
Default settings	-	-

3.5.5.2. "Device Temperature" status

The status of the "Device temperature" gives information on the validity of this signal. The status is structured as a bit field.

Signal properties	Value	Additional information
measuring range min.	-	BITFIELD; Bitwert 0 /FALSE/inaktiv
measuring range max.	-	BITFIELD; Bit value 1 /TRUE/active
Resolution	-	
Offset	-	
Data type	*UNSIGNED8*	BITFIELD
Data length	8	Bit
Mappable	*TPDO*	ro
Process value index	**3613.1**	Device temperature status
Default settings	-	-

Design of BITFIELD status "Device temperature"

In the following, the meaning of the individual identifiers in a BITFIELD are described.

The bit 0 is set if the value is not valid due to an error in the measured value detection.

The entry can be mapped in the TPDO.

Bit	
0	**Not valid**
1	Reserved
2	Reserved
3	Reserved
4	Reserved
5	Reserved
6	Reserved
7	Reserved

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3.6. Events

Events are information which can occur either spontaneously or time-controlled. They generally contain additional information on the current device status or of its status change.

3.6.1. Error messages

The following table describes the EMCY error numbers (*EMCY-EC*) supported and sent by the measurement system. The general description of the function principle and the structure of the error messages is explained in chapter *4.4.5 EMCY*.

The error register (see *4.4.5 EMCY*) transmitted via byte 2 of the EMCY is described below:

- **General**
  - Object: *Error Register*
  - Chapter: *4.5.4.1 Error management (General communication* objects)
- **Manufacturer-specific**
  - Chapter: *3.5.3 Device profile-specific parameters*

EMCY-EC	Error designation	Description
0000h	**No error**	Device reports return to error-free operation
	Manufacturer-specific	0
8120h	**CAN in "error passive"**	The device's internal CAN controller has changed to the CAN status "error passive". This error can occur during normal network operation and disappear again. This is evidence of problems in the network.
	Manufacturer-specific	*0*
8140h	**Recover from Bus-off**	The device's internal CAN controller has changed to the CAN error status "bus-off". Evidence of problems in the network.
	Manufacturer-specific	*0*
FF00h	**Device-specific error**	General device-specific error The occurred error is specified more in detail in the manufacturer-specific section of the error message.
	Manufacturer-specific	Low-Word of the *Manufacturer status register*

Example of an EMCY error message:

ID [hex]	Daten [hex]
081 EMCY	20 81 11 00 00 00 00 00 [8120, 11] Manufacturer spec.

EMCY-EC	8120h	CAN in error passive
Error Register	81h	(10000001b) → Bit 0 u. 4 set: „Generic“&„Communication“
Manufacturer specific	0000h	general error

3.6.2. Device state

The measurement system supports the heartbeat protocol; for a description, see chapter *4.4.3 Heartbeat*.

3.6.3. Device-specific PDO events

The device supports the device profile-specific results in CiA 404. See ***AI interrupt delta input PV*** (Indices: x133h, x134h, x135h, x136h)

Device profile-specific results are only active with an active "Transmission type" 255. See.***Transmission type***.

General information on PDO events:

- *4.5.4.6 RPDO communication parameter*
- *4.5.4.8 TPDO communication parameter*
- *4.6.2.1 Event driven*

3.6.4. Product-specific SSC events

For ETS 4100S it is specifically defined whether and how many SSC events will be used and what these events do represent. SSC events are usually counters which are mapped onto an object. See chapter *3.5.2.4 Parameters for smart functions "switching channels" and "*counters"*.*

3.7. Error management

Errors are recognised, managed and made available the measurement system in several different ways. On the one hand, there are errors occurring during processing of the process data and on the other hand, there are general device errors. All kinds of errors are provided as parameters (objects in the OD) and can be read out at any time; see chapter *4.6.1 SDO*.

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3.7.1. Error behaviour

How the measurement system will react to an occurring error depends on the error type and the device configuration of the error behaviour.

In the event of process data errors, the higher-level control has to decide for itself what should be done, based on the information from the associated status signal. The measurement system itself changes its operating status (see chapter *4.4 Network Management*) depending on the settings of the error behaviour.

In the case of general device errors, such as communication or configuration errors, it is possible to configure which operation mode the measurement system should take on if an error occurs via the parameter ***Error*** behaviour.

Error behaviour in case of process data errors, see chapter *3.7.2 Process data error*.

3.7.2. Process data error

The process data errors are made available as status signals. The signals should always be evaluated together with their related process values.

If an error occurs during process signal processing, due to which the signal becomes invalid, this is indicated by the "not valid" bit in the status, see object **6150.0** AI Status Fluid temperature. Setting of this bit also leads to setting of an error in the *Error register*, and, consequently sending an EMCY error message as well, see chapter 3.6.1 Error messages.

The evaluation of the fluid temperature status, *3.3.3 Status "Fluid temperature",* should always be evaluated together with the process values listed below:

- *3.3.2 Signal "fluid temperature"*

3.7.3. General error management

In addition to process-data related status errors, general error objects are also provided by the measurement system. The characteristics or additions diverging from the general implementation are described in the following.

Supported:

- General error register: *Error register*
- Specific error register: *Manufacturer status register*
- Error memory: *Pre-defined error field*

Name	Index	Sub	Type	Acc	PDO
Manufacturer status register	**1002h**	0	UNSIGNED32	ro	TP

E

Describes the device status

Error codes
F: Device is ready for use for the customer
E: Error is sent via EMCY message

Bit no.	***Value***	***F***	***E***	***Description***	***NOTICE***
0	0001	X	X	Error while loading the user settings	This error can only be removed by storing/restoring and subsequent reinitialisation of the device (Power off / Power on).
1	0002			Reserved	
2	0004			Reserved	
3	0008			Reserved	
4	0010	X	X	Errror occurred during temperature monitoring	The temperature value is faulty
5	0020	X	X	Error during fluid temperature detection	The fluid temperature value is faulty
6	0040	X	X	Error while loading the I4.0 settings	This error can only be removed by reinitialisation of the device (Power off / Power on)
7	0080	X	X	Error occurred during device temperature detection	The device temperature value is faulty
8	0100	X	X	Overflow of the receive queue of the CAN controller	This error can only be removed by reinitialisation of the device (Power off / Power on)
9 .. 12	-			Reserved	
13	2000			The CAN node cannot be started	Device always starts in production mode
14 .. 15				Reserved	

Pre-defined error field **1003h** *ARRAY*

General, see chapter *4.5.4.1 Error management (General communication* objects).

Standard error field 1 … **1003h** **1** … [1003.0] UNSIGNED32 ro

When sending an *EMCY*, the device will add the related error to the error list. The maximum amount of errors is defined to max. 10 entries for the ETS 4x00 measurement system series.

A general description of the parameters can be found under: ***Standard error field 1*** in chapter 4.5.4.1.

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In the ETS 4x00 and ETS 4x00Smart, the content of the entry is always a combination of the "*emergency error code*" (EMCY-EC) (16 bits) and a device-specific error number:

```
1003.x UNSIGNED32

Bit: 31   –    16 | 15   –    0
     Error number|   EMCY-EC
     (UNSIGNED16) | (UNSIGNED16)

Example:         0006 8140h        → Recover from BUSOFF
```

Error numbers:

1 Errors while loading the user configuration; Error persists after having occurred for the first time.

3 …

3.7.4. Error events

Errors causing a change in the general error register (see object: *Error register*) are also sent as a separate error event; see chapter:

- *3.6.1 Error messages*
- *4.4.5 EMCY*

3.8. LSS Protocol support

All measurement systems of the ETS 4100 and ETS 4100S series support the LSS protocol in the way described in chapter *4.7 Layer setting services (LSS) Protocol.*

4. Protocol description CANopen

Below, please find the description of the CANopen protocol used by the measurement system. Device-specific settings and behaviour are described in the different subsections in chapter *3 Product interface*.

4.1. General

The various original documents which have been used for the implementation of the device can be found in the operating instructions.

> The following description makes **no** claim to be complete. Its only aim is to facilitate the user's work with the CANopen device by HYDAC ELECTRONIC GmbH. If further information should be required, the documents of the CiA, which are referred to in this document and in the related user manual, are applicable.

4.2. Hardware characteristics

CAN is a **Bus system** and therefore all network participants will be connected to the same bus cable - parallel operation. On the contrary, the Ethernet, which is usually used in office communication, only connects one participant with one other at one time. For the connection between several participants, additional hardware, i.e. a switch, is necessary. This is **not** necessary when using CAN. How the network has to be organised is described in the following chapter *4.2.3 Topology*.

CAN mainly has 2 **signal lines**: **CAN-H** and **CAN-L**. Data transmission is performed via these two lines, see chapter *4.2.2 Signal* level.

Each **network participant is equal** in a CAN network. This means that each of the participants is able and allowed to send messages. If a participant sends a message, all the others receive the message and decide on their own whether it is relevant for them or not.

In the case of a **competing access** of several participants, CAN will start **prioritising messages**. This will avoid collisions occurring as they do in other systems. The prioritising of messages is carried out via the CAN-ID, where the CAN-ID 0 has the highest priority, see chapter *4.3.2 Meaning of the* CAN-ID*.*

A network participant is only allowed to start sending once a message has been transmitted completely. If two participants start sending at the same time, the participant with the higher priority message will always "win". The structure of a message is described in chapter *4.3.1 Basic structure of a* CAN data message.

The transmission of information in CAN networks is bit-oriented and uses a recessive and a dominant signal status. The dominant signal status is able to overwrite the recessive one. As a participant which is sending will read back each written bit immediately, it can also recognise when its own message has been overwritten. In this case, it will immediately discontinue further data transmission.

The participant which has interrupted transmission will try to reinitialise its transmission after the higher prioritised message has been sent. In doing so, no messages will be lost.

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4.2.1. Wiring

CAN does not require any complicated wire connections. To connect the network participants, one twisted pair of wires should be used. The pair of wires is for the transmission of the signals CAN-H and CAN-L. Non-twisted cables should be avoided. The recommended core diameter depends on the length and has an average of between 0.34 and 0.6 mm^2.

Almost all CAN connections provide an additional CAN_GND and CAN_SHLD. CAN_GND corresponds with a signal mass and can be used to bring the reference potential of the network participants to one common level. CAN_SHLD is a connection which provides shielding for the signal line. In general, the CAN signal lines do not require any shielding.

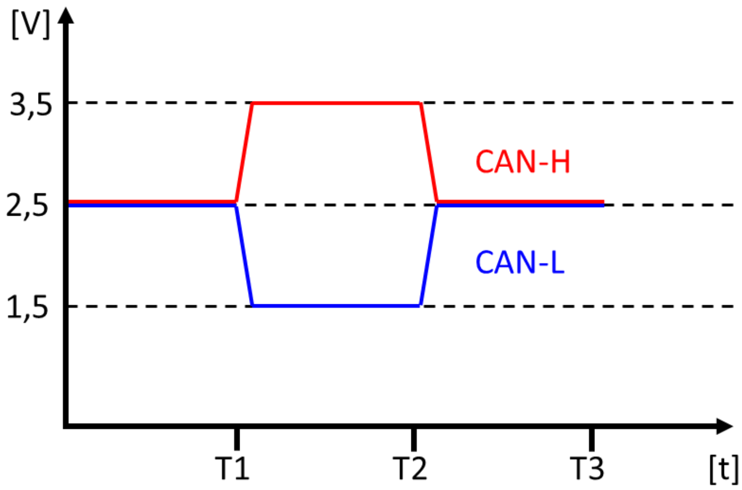
	Differences in potential between network participants should be avoided. These may damage the wire connections or the electronic unit. The connection CAN_GND is not intended for equipotential bonding.

4.2.2. Signal level

For the transmission, a symmetric voltage signal is used. This signal type has no direct relation to a signal mass. Only the voltage difference between both signal lines will be evaluated. This type of signal transmission has significant benefits in the case of interfering signals, as these will affect both signal lines equally and will be excluded at the subtraction.

In the event of a dominant signal, the signal line CAN-H will move to a higher voltage level and the CAN-L signal line will move to a lower voltage level.

4.2.2.1. Diagram signal level CAN-high-speed



- In the event of a recessive signal status, the differential voltage is ~ 0V.
- In the event of a dominant signal status, the differential voltage is ~ 2V.

  This diagram explains why a dominant signal status is able to overwrite a recessive one. This mechanism is used for the prioritisation of messages; see chapters *4.2 Hardware characteristics* and *4.3.2 Meaning of the CAN-ID*.

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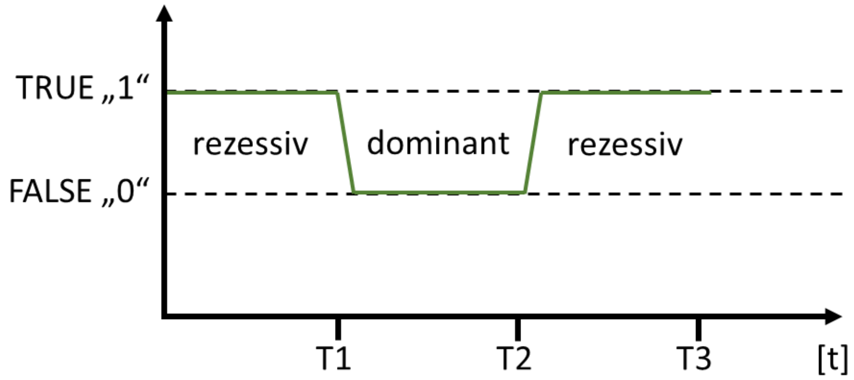
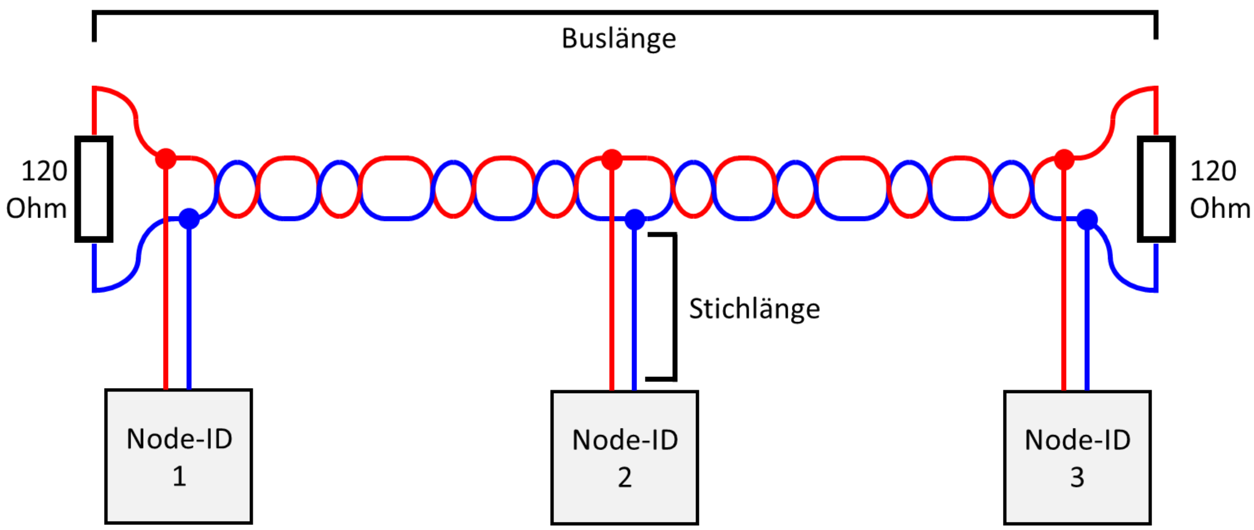
4.2.2.2. Diagram signal logic



4.2.3. Topology

As explained in chapter *4.2 Hardware* characteristics, the topology of CAN is the Bus. This means that the CAN has a direct connection line which reaches from the first to the last participant. Each individual participant is directly connected to the signal lines CAN-H and CAN-L. At both ends of the main bus (the longest direct connection line) the bus line has to be terminated using a resistance of 120 Ohm.

For the length of the main bus as well as for the length of the individual stub cable between the bus and the network participants, the maximum line lengths, described in chapter *4.2.5 Transmission speed*, should be strictly adhered to.



If the max. line lengths are not adhered to or if the bus lines are not terminated properly, this may lead to interference during transmission, see chapter *4.3.4 Troubleshooting*.

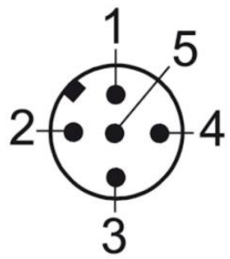
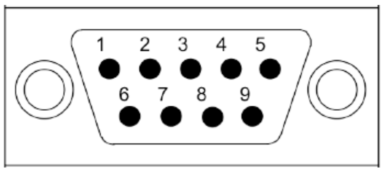
A CAN network can usually include up to 32 network participants.

4.2.4. Standard pin connections

The following two connector types with the pin connection shown below are very often used with CAN. The pin connection corresponds with the requirements of the CiA 303-1.

Which connector plug is used by the device in question should be taken from the operating instructions or the relevant data sheet.

- M12*1 5 pole plugs for sensors and actuators
- DSUB 9 pole socket for controllers (PC or PLC).

Plug connector	Pin	Description	
	1	CAN_SHLD	*Shielding*
	2	CAN_V+	optional supply voltage
	3	CAN_GND	*CAN Signal mass*
	4	CAN_H	*Signal line dominant "High"*
	5	CAN_L	*Signal line dominant "Low"*
	1		
	2	CAN_L	*Signal line dominant "Low"*
	3	CAN_GND	*CAN Signal mass*
	4		
	5	CAN_SHLD	*Shielding*
	6		
	7	CAN_H	*Signal line dominant "High"*
	8		
	9	CAN_V+	optional supply voltage

4.2.5. Transmission speed

The transmission speed of CAN can be selected in particular areas. It is indicated in **bit/s** and is also referred to as **Baud rate.** The Baud rate of a device can be changed using an OD parameter; see chapter *3.1.3.2 Changing the Baud* rate and object: *Baud* rate.

A distinctive feature for CAN is that the Baud rate has a high impact on the maximum length of the wiring (see chapter *4.2.1 Wiring).* The length of the bus as well as of the stub cables depends on the transmission speed; see chapter *4.2.3 Topology*. The table below explains the dependences:

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Bit rate [kbit/s]	Bus length [m]	Stub length [m]	Bit length [µs]
1000	25	0.3	1
800	50	0.5	1.25
500	100	0.8	2
250	250	1.5	4
125	500	3	8
50	1000	5	20
20	2500	7	50
10	5000	10	100

4.3. Data communication

The basic information for the data exchange between two or more network participants is given below.

As explained in chapter *4.2 Hardware characteristics*, all participants of a CAN network are able to send messages. A message which is sent is also received by each participant. For this reason, the messages are referred to as "broadcasts". This is because they can be compared to a radio station sending information, a news programme for instance, which all radio receivers are able to hear/receive.

The type of message is defined via the CAN-ID (see chapter *4.3.2 Meaning of the CAN-ID*) and the receiver is able to set a filter, to define which messages it wants to receive - just like setting (filtering) a frequency to receive a particular radio station.

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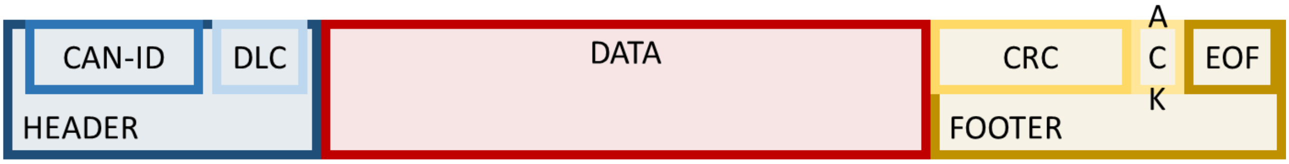
4.3.1. Basic structure of a CAN data message

The data message is the most important message in a CAN network. As the name suggests, it is used for the exchange of data/information between the network participants.

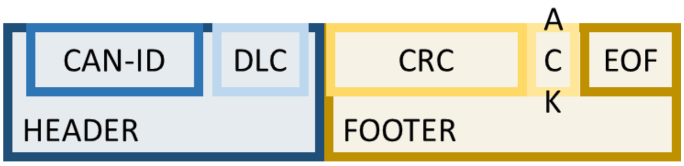


A data message consists of three sections:

- HEADER - The message head synchronises the network participants and informs the consumer about the content and the length of the message.
- DATA - This section is for the useful data, i.e. the information which is supposed to be transmitted from the producer to the consumer.
- FOOTER – Contains the checksum, a message confirmation as well as an identifier which marks the end of the entire message.

A special feature of CAN messages is that they can also represent valid information without the useful data. The DLC of the HEADER states how many useful data bytes a message contains. This section defines the amount of data bytes in the DATA area and can receive the valid values 0-8. This also results in the maximum length of the useful data (8 bytes or 64 bits).

Example of a CAN message without useful data; DLC = 0:



The length of the entire message depends on two factors. Firstly, it depends strongly on the amount of useful data. It also depends on the length of the CAN-ID; see chapter *4.3.2 Meaning of the* CAN-ID*.*

The shortest possible message (11 bit CAN-ID, DLC = 0) has a bit length of 47 bits. This message would require 188 µs for a Baud rate of 250 kbit/s and a maximum of 4800 messages of this type would be able to be transmitted per second (~90 % Bus load).

For the longest possible message (29 bits CAN-ID, DLC = 8), the length of the message at 250 kbit/s (4 µs /bit) would be as follows: message length = 129 bits, transmission time per message = 516 µs (~0.5 ms) and approx. 1760 messages per second (~90 % Bus load).

The structure of other message types, such as "Error frame" or "Remote frame", will not be explained herein, as they either play a subordinate role or are handled by the device's internal communication controller.

4.3.2. Meaning of the CAN-ID

As described in chapter *4.2 Hardware characteristics,* CAN is able to prioritise incoming messages. The CAN-ID is critical for this. It is sent within the first section of the HEADER, as has been explained in chapter *4.3.1 Basic structure of a CAN data message*. As the network participant may not send before complete transmission of a message, the CAN-ID can be used to prioritise, using the mechanism of the recessive and dominant signal statuses (see chapter *4.2.2 Signal level*).

The priority of a message depends on the value of the CAN-ID.

- The lower the CAN-ID, the higher the priority of the message.
- CAN-ID = 0 has the highest possible priority.

CAN does not know any direct addresses of the participants. The CAN-ID defines which importance a message has. In CANopen protocol, for example, the CAN-ID 0 identifies the NMT message - network management, (see chapter *4.4 Network Management*).

Whereas CANopen takes the opportunity to structure the CAN-ID and to combine the importance (service identification) with the participant's address; i.e. the CAN-ID of the first process data object is defined by 180h + Node-ID.

In CANopen, the synonym COB-ID is often used instead of CAN-ID. The COB-ID can either be the CAN-ID itself, or the combination of the basic CAN-ID and the Node-ID, which becomes a concrete CAN-ID during the life time of the device; i. e. object *COB-ID emergency message*.

The most important CANopen services and the assignment to their CAN-ID are listed below:

Service	CAN-ID	Note
NMT	0	*Network management* The *NMT Master* must always be able to reach all the participants for the management of the network. For this purpose, this service has the highest possible CAN priority.
SYNC	80h	*Synchronisation signal*
EMCY	80h+Node-ID	*Error event*
SRDO	101h – 180h	Safety-relevant data object see chapter *1.1°Scope* of application
PDO	181h – 57Fh	*Process data objects*
SDO	581h – 67Fh	*Access to OD parameters via service objects*
LSS	7E4h – 7E5h	*Layer setting services*

4.3.3. Meaning of the Node-ID

As explained in chapter *4.3.2 Meaning of the* CAN-ID, no particular network participant can be addressed directly only using the CAN-ID. However, since it is essential for most auto-

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mation tasks to address one particular network participant, the **Node-ID** was introduced as the **participant address** in CANopen.

- The Node-ID of a participant always has to be defined in the way that it is always clear within a network, which means, it may never exist more than once.
- The valid value range of the Node-ID is 01h to 7Fh (1d to 127d), i. e. there can only be max. 127 different participants within one CANopen network.

There are different ways to change the Node-ID:

- Default settings: *3.1.1 CANopen default settings*
- *3.1.3.1 Changing the device address* (*Node-ID)*
- *4.7 Layer setting services (LSS) Protocol*
- Object: *Node ID*

4.3.4. Troubleshooting

CAN has its own error management, which is composed of 3 different error statuses. The switching between the different error states is managed via internal error counters (TEC: transmit error counter, REC: receive error counter). A more detailed description of the bus behaviour can be found in ISO 11898-1.

If a participant recognises an error when sending, or if one of the recipients reports a transmission error by sending back a particular error message, the producer will repeat sending its failed message as soon as possible.

- **Error active**

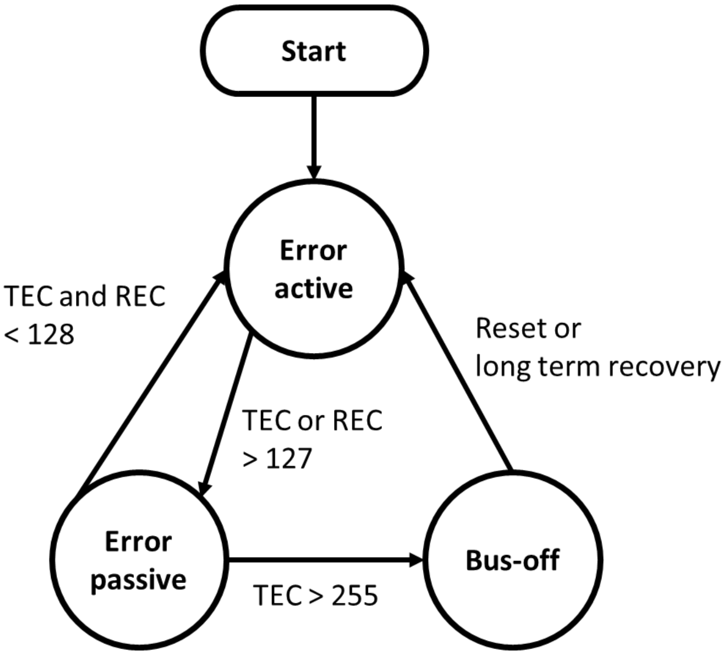
  This the "normal" operating state of a network participant. In this state, a participant is able to send messages as well as actively inform other participants about communication errors which it has detected.

- **Error passive**

  The participant is in a "temporary" error state. In this state, messages can still be sent and received. After sending a message, however, the participant will maintain a certain delay before sending the next message. This gives the participants which do not show any interference the opportunity to send their messages earlier. This mechanism is supposed to reduce network traffic if there is one interfering participant.

- **Bus-off**

  The participant is in an error state. It is neither able to send nor to acknowledge any messages. This state can only be left if the participant is actively reset or if no errors occur at the bus within a long period of time. After their return, the error counters are reset and the participant is returned to the "error active" state.



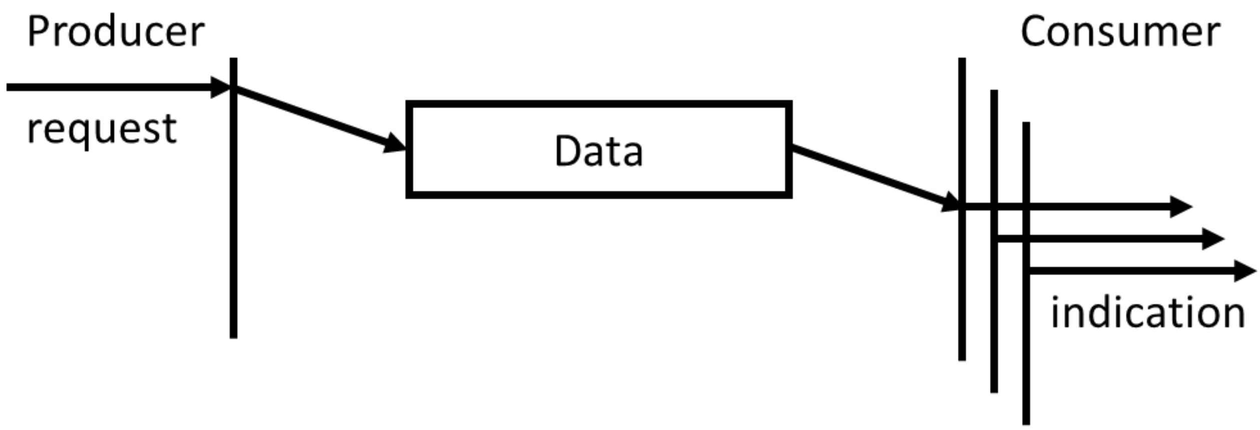
4.3.5. Communication types

As described in chapter *4.3 Data* communication*,* CAN uses data packages for the transmission of information. To make the communication process run smoothly, there are different models for how the data flow between two network participants should be organised.

The communication types used most frequently with CANopen are described below. The left side of the diagrams always represents the information source which generates the messages and sends them. The central section of the diagram represents the transmission via the network and the right section represents one or more consumers.

4.3.5.1. Producer - Consumer

The "producer - consumer" model describes how a participant generates information which one or more participants can receive and process. The advantage of this model is that it is not necessary for each individual participant to be informed about the same circumstances. Instead, any participant for whom the information is of interest will receive the information at the same time in one data transmission.



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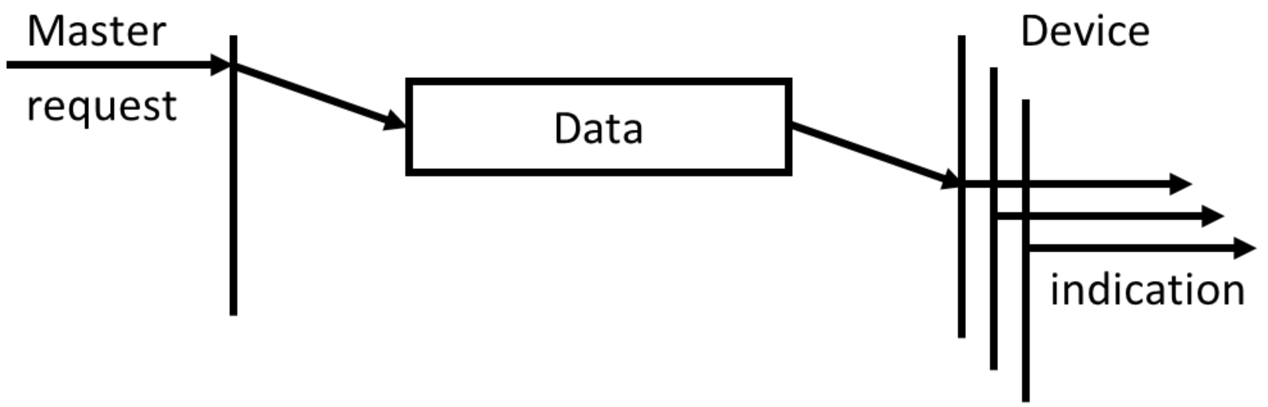
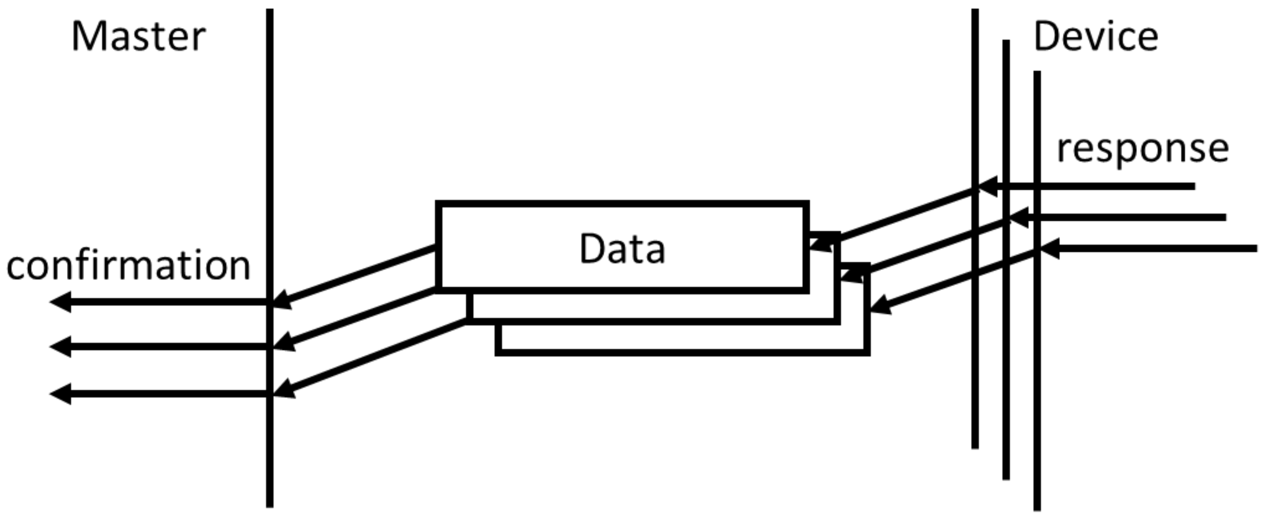
4.3.5.2. Master – Device

In a similar way to the "Producer – Consumer" model, the "Master – Device" model (see chapter *1.6 Changes in technical terms in the context* of "political correctness") is able to reach several consumers at a time. In this particular case, however, there is only one firmly defined "producer", the master, who informs or instructs all other participants ("devices"). Which participant works as a master is defined during the architecture phase of the system design period.

This model can, for instance, be used by a CANopen manager to administrate the network by acting as a NMT master (see chapter *4.4.2 NMT*). It is also used for the synchronisation of the process data; see chapter 4.6.2.2 SYNC.



In some "master - device" implementations, the "master-request" will be responded to by the participants ("devices") via a "response". This procedure is used with the LSS protocol, for example. In doing this, the LSS master will be informed that one or several LSS devices have performed the required status change, see chapter *4.7 Layer setting services (LSS) Protocol*.



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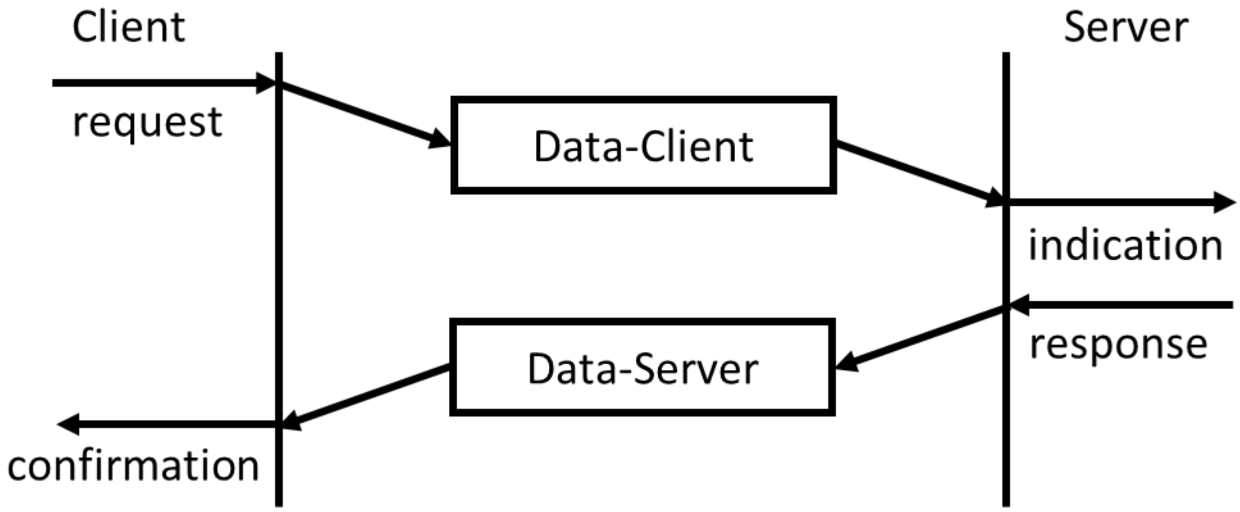
4.3.5.3. Request – Response / Client – Server

The "Request – Response" model enables one particular participant to request information from another particular participant. The client communicates to the recipient (server) about the information that it wants (data request). This is usually done via data from the data package. Theoretically, such a request may also only consist of a message without the data, see chapter *4.3.1 Basic structure of a* CAN data message DLC = 0.

The recipient takes on the function of a server, administrating a pool of data or services, which can be requested directly from that pool by a client. An example from our daily practice could also be requesting a website on the internet by entering an internet address (URL) into the internet browser. The request is comparable with the entry of the address and the response is the page that is subsequently loaded and displayed.



From the point of view of CANopen, this type of communication is used when accessing the OD, see chapters *4.5 The Object* Dictionary and *4.6.1 SDO*.

4.4. Network Management

In automatisation of machines, it is crucial to keep the communication under control. The CANopen manager is usually responsible for this task. This manager is usually represented by a superordinate control, e. g. a PLC or a mobile control unit.

There are several different operating states which can be adopted by the different participants, under the control of the CANopen manager. Depending on the operating state of a participant, it can provide (or not provide) certain services autonomously, see chapter *4.4.1 Overview of* network states. The administration of the network state is carried out via the "network control" service, see chapter *4.4.2 NMT*.

The two most important states are:

- **Pre-Operational**

  This state serves to parameterise a participant suitable for a specific application, see chapters *4.6.1 SDO* and *4.5 The Object* Dictionary. In addition, further services are carried out, such as: *4.4.3 Heartbeat.*

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A participant adopts this state automatically after start-up and usually remains in this state until a explicit command for status change has been received. The participant's start-up behaviour can be controlled via the object "*NMT startup*".

Important note: In this state, **no process data** can be received or sent.

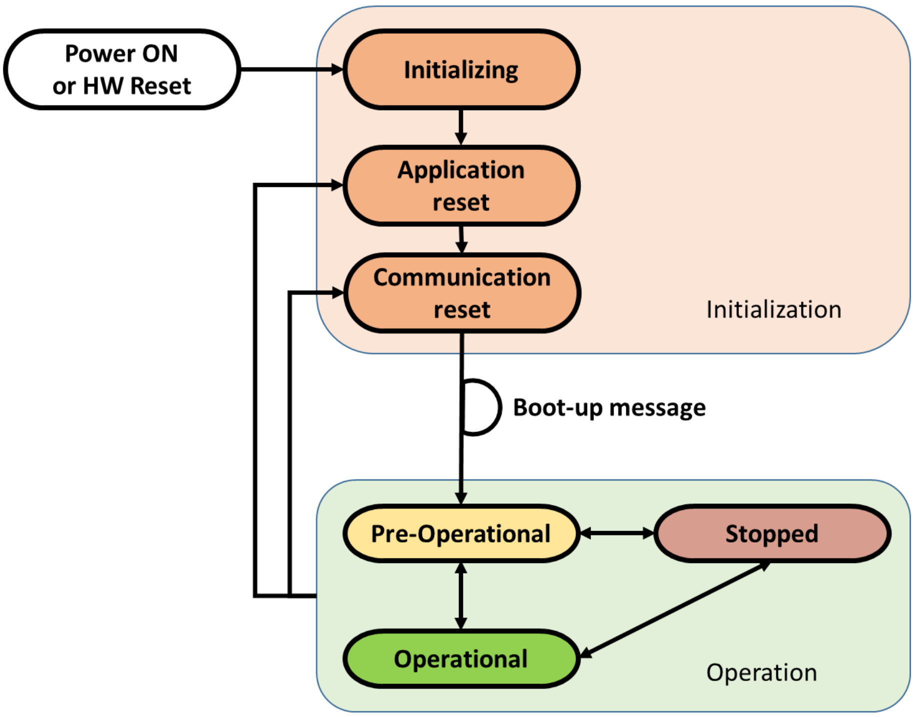
- **Operational**

  The "operational" state is the normal operating state of a participant. Almost all CANopen communication services can be used. It is only this state which enables the participants to receive and process the process data and generate and send their own process data, see chapters *4.6.2 PDO* and *4.6.3 SRDO.*

  In this operating state, the parameters can also be read. The ability to change parameters is limited, however, see *4.6.2.3 PDO Mapping*.

4.4.1. Overview of network states

In general, the states are subdivided into the following categories: initialisation and operation of a participant. The initialisation phase is performed automatically after applying the supply voltage. After successful initialisation, the participant sends a "*Boot-Up*" message by means of which the *Node-ID* of a participant can be identified; see also chapter *4.4.3 Heartbeat*.



After successful initialisation, there are 3 different operating states available. The most important states, "pre-operational" and "operational", were already explained in chapter *4.4 Network Management*.

In the "stopped" state, only the network services (see *4.4.2 NMT*) and error services (see *4.4.3 Heartbeat*) are active. All the other services are not available.

The following table provides an overview of what services are available in the different operating states:

Service ID	Pre-Operational	Operational	Stopped
PDO		X	
SRDO		X	
SDO	X	X	
SYNC	X	X	
TIME	X	X	
EMCY	X	X	
Heartbeat	X	X	X
LSS	X		X
NMT	X	X	X

4.4.2. NMT

The administration of the network states is carried out via the "network control" service. For this purpose, there is a defined NMT master which gives the command (using a NMT message) to each individual participant (device) to change their state, NMT = **N**etwork **M**anagement.

The "Network Control" service is performed via the *Master – Device*communication model. The CANopen Manager (controller) generally takes over the role of the NMT Master

As this service makes the decisions on the interaction between the participants in the network, it has been assigned the most important priority; see chapters *4.3.2 Meaning of the* CAN-ID and *4.3.1 Basic structure of a* CAN data message.

The NMT message has a data length of 2 bytes, each of which has a particular meaning which is documented below.

Field name	Content	Meaning	
CAN-ID	0	CAN-ID of the message	
DLC	2	Data length of the message in bytes	
BYTE 0	Command	01h	Start node Participant should switch to "Operational" state.
		02h	Stop node Participant should switch to "Stopped" state.
		80h	Enter Pre-Operational Participant should switch to "Pre-operational" state.

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Field name	Content	Meaning	
		81h	Reset node Participant should be restarted.
		82h	Reset communication Participant should restart its communication layer.
BYTE 1	Node ID	0d	Message is being processed by all participants
		1-127d	Node-ID of the participant to be changed.

Example of a signal from the NMT Master telling all network participants to change to the operating state "*Operational*" → NMT "Start all nodes".

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Node ID						
000h Tx	01h	00h						

4.4.3. Heartbeat

The heartbeat protocol enables one participant to inform other participants within the network about its current operating state.

This service is implemented according to the *4.3.5.1 Producer - Consumer* model.

The message needs to be activated explicitly and is sent on a cyclical basis. The heartbeat can be activated and the repeat rate can be configured via the object "*Producer* heartbeat time*"*.

Should the heartbeat consumer report the absence of a heartbeat message, it will inform its superordinate application software about this event. The application should then react in the appropriate way.

The message has a data length of one byte, which reports the current state of the participant.

Field name	Content	Meaning	
COB-ID	700h + Node-ID	CAN-ID of the message is calculated during operation from the basic CAN-ID and the Node-ID of the participant.	
DLC	1	Data length of the message in bytes	
BYTE 0	*Status*	00h	Boot-up

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Field name	Content	Meaning	
			The participant reports a system start.
		04h	Stopped Participant is in the "Stopped" mode.
		05h	Operational Participant is in the "Operational" mode.
		7Fh	Pre-Operational Participant is in the "Pre-operational" mode.

Example of a heartbeat signal of a device with Node-ID = 1 which is currently in the operating mode "*Pre-Operational*".

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	Status							
701h Rx	7Fh							

4.4.4. Example NMT behaviour

In the following example of the CAN protocol, one individual participant with the Node-ID = 1 is connected to a CANopen manager (*NMT Master*) and is re-initialised at the beginning of the recording (power ON).

Description of the subsequent process:

- After successful initialisation, the device sends its "boot-up" message.
- After a defined time ,the manager starts all the participants.
  - The device starts sending its process data *TPDO1*.
- After having waited a further defined period, the manager sends an additional signal to change to "*Pre-Operational*".
  - The device stops the sending of process data.
- The manager writes onto the object 5300 in the device (Node-ID = 1).
  - The device confirms that the writing access has been successful.
- After having waited a further defined period, the manager sends an additional signal to change to "*Stopped*".
- The manager again attempts to write onto the object 5300 in the device (Node-ID = 1).
  - The inquiry is not responded to by the device.

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The participant is configured as follows:

Range	Characteristic	Default settings
General Settings	Node ID	1
	Power ON Status	*Pre-Operational*
TPDO1	Transmission Type	254
	Event Timer	1000 ms
Heartbeat	Event Timer	1000 ms

```
CAN-ID (hex)
|      Direction: Tx (ECU → Device); Rx (Device → ECU)
|      |  Data Length
|      |  |  Data Bytes (hex)
|      |  |  |
+---   +- +  +- -- -- -- -- -- -- --
Boot-up Node-ID = 1
0701  Rx 1  00
Heartbeat Node-ID = 1, Status = „Pre-Operational“
0701  Rx 1  7F
0701  Rx 1  7F
…

NMT command "start, all nodes".
0000  Tx 2  01 00
TPDO1 Node-ID = 1
0181  Rx 5  53 00 44 00 00
Heartbeat Node-ID = 1, Status = "Operational"
0701  Rx 1  05
0181  Rx 5  53 00 44 00 00
0701  Rx 1  05
…

NMT command "Enter Pre-Operational, all nodes"
0000  Tx 2  80 00
Heartbeat Node-ID = 1, Status = „Pre-Operational“
0701  Rx 1  7F
0701  Rx 1  7F
SDO Download Request, 5300.0 = 1
0601  Tx 8  2F 00 53 00 01 00 00 00
SDO Download Response, 5300.0 OK
0581  Rx 8  60 00 53 00 00 00 00 00
→ TPDO1 is no longer sent
…
```

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```
NMT command "stop all nodes"
0000  Tx 2  02 00
Heartbeat Node-ID = 1, Status = "Stopped"
0701  Rx 1  04
0701  Rx 1  04
SDO Download Request, 5300.0 = 1
0601  Tx 8  2F 00 53 00 01 00 00 00
→ Not received any SDO Download Response; Node 1 in "stopped"
0701  Rx 1  04
```

4.4.5. EMCY

With EMCY messages, the device can inform other participants in the network when it has detected an error.

EMCY messages are implemented according to the "producer/consumer" model; see chapter *4.3.5.1 Producer - Consumer*.

An EMCY message is sent only once. Sending is performed whenever an error has been recognised in the device.

If the error has been recognised for the first time, the corresponding bit of the error register (see object "*Error register*") is set. If all the bits in the error register have been erased, the EMCY message with the error number 0000h is sent. This particular EMCY serves as an identifier which signalises that all error states have been reset and that the device has returned to trouble-free operation.

An EMCY message has a length of 8 bytes. The first bytes contain the "emergency error code" (EMCY-EC) (2 bytes), specified in the CiA 301 and the *Error register* (1 byte) of the device. The remaining 5 bytes are manufacturer-specific and usually also device-specific.

In order to avoid an accumulation of EMCY messages (for instance in the event of a faulty CANbus connection), a minimum waiting delay between two EMCY messages can be defined "*Inhibit time EMCY"* .

How the device should behave when an error has occurred can be defined via the object "*Error* behaviour". A response could be a change in the activated operation mode; see chapter *4.4.1 Overview of* network states.

Field name	**Content**	**Meaning**
COB-ID	80h + Node-ID	CAN-ID of the message is calculated during operation from the basic CAN-ID and the Node-ID of the participant.
DLC	8	Data length of the message in bytes
BYTE 0, 1	emergency error code "EMCY-EC"	Error number of the EMCY event. The error numbers supported by the device are described in chapter *3.6.1 Error* messages*.* Data type: *UNSIGNED16*

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Field name	Content	Meaning
BYTE 2	*Error register* "ErReg"	The content of the object "Error Register" is copied into the message when an EMCY event occurs. Data type: *UNSIGNED8*
BYTE 3 - 7	Manufacturer specific error field (MSEF)	Manufacturer-specific and device-specific additional misinformation. Description of the content of this data field; see chapter *3.6.1 Error* messages. In many of our devices the first 2 bytes of this data field contain the information on both lowest bytes (Low-WORD) of the object "*Manufacturer status* register" when an error occurs. Data type: manufacturer-specific

EMCY messages of a HYDAC ELECTRONIC linear position transmitter are shown below as an example with Node-ID = 1:

- The network connection between the CANopen manager and the device has been disrupted.
  - EMCY-EC 8120h → *CAN in "error passive"*
  - *Error Register* 11h → Bit "Generic" & "Communication error" is set
  - MSEF 00h → no additional information
- Linear position sensor motion detected outside of the measuring range limits.
  - EMCY-EC FF00h → *device-specific error*
  - *Error Register* 91h → Bit "Generic" & "device-specific error" is set → Bit "Communication error" is still set
  - MSEF 10h → Measuring range exceedance recognised
- Linear position sensor has been moved back to its valid measuring range.
  - EMCY-EC 0000h → *No error*
  - *Error Register* 00h → "no error"
  - MSEF 00h → no additional information

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	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	EMCY-EC		ErReg	manufacturer-specific error field (MSEF)				
	LowBy	HighBy						
081h Rx	20h	81h	11h	00h	00h	00h	00h	00h
081h Rx	00h	FFh	91h	10h	00h	00h	00h	00h
081h Rx	00h	00h	00h	00h	00h	00h	00h	00h

4.5. The Object Dictionary

The "object dictionary" (OD) is the data base of the device. All process values are stored here as well as all settings and device properties. The individual values can be read, and partly also written to via SDO commands (see chapter *4.6.1 SDO*).

The individual entries in the OD are referred to as objects. An object can either represent an individual value or a combined data entry. Combined data entries are, for instance, arrays or structures; see chapter *2.4.6 ARRAY* and *2.4.7 RECORD*.

There are objects, which may only be changed under particular system conditions, or which enter into effect in the event of particular system condition changes only, see chapter *4.4.2 NMT*.

The OD is subdivided into different sections. The most important and applicable for all devices are listed below (see chapter *4.5.4* and following). Device-specific entries are described in the chapter *3.5 Parameters*. The classification is made via pre-defined object index sections, see CiA 301.

The HYDAC standards for the structure of an OD are explained below. There may be deviations from these standards, depending on the device. In the event of a deviation, they are described in chapter *3.5 Parameters*.

4.5.1. General overview

In this chapter, the general characteristics of the OD will be explained - how a particular object can be selected, which access limitations there are and which different properties objects have in this context.

The abstract term "object" is replaced by the more defined term "parameter", mainly for the OD in the context of the product description (see chapter 3.5 Parameter).

In the context of CANopen, the term "object" does not only include an entry in the OD. It may also refer to a communication object; see chapter 4.6.1 SDO or 4.6.2 PDO.

4.5.1.1. Addressing

Each entry in the OD is addressed via an object index. The index value identifies the specific object. If the object represents the combined data type, the index will be subdivided into further sub-indices. A specific value from this type of structure will therefore be addressed via the specification of the index and the sub-index.

> The notation of an **object index** will always be represented by **hexadecimals**, whereas the **sub-index** will always be represented by **decimals.**

At first, the index of the main object will be specified and separated from the index of the relevant sub-object with a ".". Addressing a particular object will, therefore, be represented as follows:

<index>.<subindex>

1018.2 → Identity object.Product code = 928037 s. *4.5.3 OD Example*

When accessing a single object in the OD, the sub-index 0 is always specified for the addressing, see chapter *4.6.1 SDO*.

1005.0 → COB-ID SYNC = 128 (80h)

In a device, it is not necessary to have all the indexes continuously available and addressable. Gaps are usual in the OD. When accessing a non-defined object, a corresponding error message will be issued.

4.5.1.2. Object access types

Also referred to as "access" or "acc." below.

- **ro** read only
  Object is readable only, the content may change during runtime.
- **rw** read write
  Object can be read and written to, the content can also be changed during runtime by the device; i.e. object "*Producer heartbeat time"*.
- **rww** read write, process write
  Object can be read and written to. If the object is marked as "mappable" at the same time, it can only be mapped to a PDO for writing onto it, i.e. a RPDO.
- **rww** read write, process read
  Object can be read and written to. If the object is marked as "mappable" at the same time, it can only be mapped to a PDO for reading, i.e. a TPDO.
- **wo** write only
  The object can only be written but cannot be read.
- **const**
  The object can only be read, the content does not change during runtime.

> Changes to the object are always performed in the volatile device memory (RAM). In order to permanently save changes, a storing function has to be activated; see chapter *4.5.1.3 Objects serving as functions* .

4.5.1.3. Objects serving as functions

Some objects are similar to function calls. When calling up a function which is assigned to an object, the object is usually assigned a particular activation value. The writing process consequently triggers the assigned function.

> An important example of this is the feature "***Store parameters***", which should be activated for the permanent storage of object changes.

4.5.1.4. Objects serving as process data content

Some entries in the OD can be used for the transmission via a process value (PDO). The main advantage is that, doing this, the content of the object does not have to be requested explicitly via a SDO command anymore, but is permanently available in the context of process data transmission.

The object property "*mappable*" indicates that the content of the object can be transmitted via a PDO; see chapters *4.6.2 PDO* and *4.6.2.3 PDO Mapping*.

In the different object tables, all the objects which are able to be transmitted as a process value are marked in the "PDO" column as follows, i.e. object "*Error register*".

Type	Acc.	PDO
JNSIGNED8	ro	TP

TP Object can be mapped onto a **TP**DO (**T**ransmit).

RP Object can be mapped onto a **RP**DO (**R**eceive).

4.5.2. Overview of OD areas

The highlighted areas are crucial and will be described more in detail in the chapters below.

Index area		Description
0000h		Reserved
0001h	025Fh	Data types
0260h	0FFFh	Reserved
1000h	1FFFh	**Communication profile area** Communication objects

Index area		Description
2000h	5FFFh	**Manufacturer-specific profile area** Manufacturer-specific objects
6000h	9FFFh	**Standardized profile area** Objects which are defined via a device profile.
A000h	AFFFh	Network variables
B000h	BFFFh	System variables
C000h	FFFFh	Reserved

4.5.3. OD Example

The below table shows the general structure of the OD in a device. It has been generated as an extract based on the inclination sensor HIT (HE-926037-0008.eds).

The column "value" corresponds with the possible content of an object which can be read out via the addressing <index>.<subindex> by means of a *SDO commands* from an existing device.

The columns "Name", "Object type", "Access" and "Data type" provide a more detailed description of the properties of the entry; see also chapter *4.5.7 EDS Electronic Data Sheet*.

Index	Sub	Value	Name	Type	Access	Data type
…	**…**	…				
1005h		128	COB-ID SYNC	VAR	rw	*UNSIGNED32*
1008h		HIT100 0	Manufacturer device nam e	VAR	const	*STRING*
…	**…**	…				
1018h	**0**	4	Highest sub-index supported	VAR	Const	UNSIGNED8
	1	218	Vendor ID	VAR	ro	UNSIGNED32
	2	928037	Product code	VAR	ro	UNSIGNED32
	3	8	Revision number	VAR	ro	UNSIGNED32
	4	4711	Serial number	VAR	ro	UNSIGNED32
1029h	**0**	3	…	…	…	…
	1	1	…	…	…	…
	2	1	…	…	…	…
	3	1	…	…	…	…
1400h	**0**	5	…	…	…	…

Index	Sub	Value	Name	Type	Access	Data type
	1	513	…	…	…	…

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4.5.4. Communication profile area

Object index range: 1000h – 1FFFh

In the section "Communication profile area", all the settings which are necessary for the communication with the device are listed. This includes manufacturer-related or device-related information (e.g. the serial number), current error reports and the settings for the process data transmission.

The "Communication profile area" is subdivided into different sub-areas. The essential areas for this protocol description are described in the following sub-chapters.

The general area describing all the parameters for communication, see CiA 301 "General communication objects (object index range: 1000h – 1029h)" has been subdivided into the following 4 sections for better readability.

4.5.4.1. Error management (General communication objects)

Object index range: 1000h – 1029h

In this section, the objects from the section "General communication objects" are summarised. These provide information on the device status (e.g. error management).

A small number of these objects are specifically defined in the device profiles. This is relevant for the following objects:

- Error register 1001h
- Error behaviour 1029h

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Name	Index	Sub	Type	Acc.	PDO
Error register	**1001h**	0	UNSIGNED8	ro	TP

Device error status. This error status is also part of the EMCY message, see chapter *4.4.5 EMCY*.

Bit 0 **Generic error**
Indicates a general device failure, this could be an error during evaluation of the measurement signal, for example.

Bit 1 Current not supported

Bit 2 Voltage not supported

Bit 3 Pressure not supported

Bit 4 **Communication error**
Becomes active when an error has been recognised during CAN communication.

Bit 5 **Device profile specific** s. Annotation

Bit 6 Reserved

Bit 7 **manufacturer-specific**
Is activated if a manufacturer-specific error exists; see ***Manufacturer status*** register

Note: Parts of the register's signification will be individually defined by the device profiles; see chapter *3.5.3 Device profile-specific* parameters.

Name	Index	Sub	Type	Acc.	PDO
Manufacturer status register	**1002h**	0	UNSIGNED32	ro	TP

This object is an expanded error state compared with the "Error register". The lowest 16 bits (bit 0 - 15) contain the device-specific error identifiers. In the case of an error, these 16 bits will also be saved in the error memory as additional information.

The higher bits (bit 16 - 31) can contain additional status information.

If an EMCY message occurs (see chapter *4.4.5 EMCY*), the lower level 16 bits (bit 0 - 15) of the "Manufacturer status register" will be transmitted from the manufacturer-specific part of the message.

The detailed description of each individual bit's meaning can be found in the device-specific part of this documentation *3.7.3 General error* management.

Name	Index	Sub	Type	Acc.	PDO
Pre-defined error field	**1003h**		*ARRAY*		

The error list shows the errors which have occurred in the device and which were signalised via EMCY message (see *CiA 301*). The object is a combined data type in the form of a list (*ARRAY*). The individual entries are described below.

The content of this object is not stored in the persistent memory of the device and will therefore be erased after device restart.

Name	Index	Sub	Type	Acc.	PDO
Number of errors	**1003h**	**0**	UNSIGNED8	rw	

E

Name	Index	Sub	Type	Acc.	PDO

The current number of error messages saved in the error list. If no error has been detected, the content is 0. The maximum size of the list depends on the device configuration, however, for most products, the list is set to have max. 10 entries.

By setting the object to 0, any error memory that may exist is deleted. Values which are different from 0 may not be written into the object.

Standard error field 1 …	**1003h**	**1** … [1003.0]	UNSIGNED32	ro	

When sending an *EMCY*, the device will add the related error to the error list.

The content of each entry is composed of the "*emergency error code*" (EMCY-EC) (16 bit) and the lower 16 bits of the "*Manufacturer status register*" (MSR-LW).

```
Bit: 31 – 16 | 15 – 0 (UNSIGNED32)
     EMCY-EC | MSR-LW
```

Sub-index 1 contains the most recently occurred error, sub-index 2 contains the error which occurred before that. At the same time, the content of sub-index 0 defines the last valid entry in this list. Example: 1003.0 = 3 → 1003.1, 1003.2 and 1003.3 contain valid error entries.

The history is able to register a device-specific amount of errors. There is, however, at least one error memory available. If the number of error entries in the list is exceeded, the oldest entry will be overwritten.

The content of the error list will always be deleted at device start-up.

Inhibit time EMCY	**1015h**	0	UNSIGNED16	rw	

Configurable delay between two *EMCY messages*.

If several EMCY messages occur within the pre-set time period, a new EMCY message will not be sent before the time has elapsed. The EMCY error code sent corresponds with an error which has been detected within that time span.

If an EMCY event occurs which immediately disappears, **no** EMCY message will be sent.

0 No delay activated for EMCY messages.

>0 Delay time as a multiple of 100 µs

Error behaviour	**1029h**		*ARRAY*		

Definition of the device behaviour when an error occurs; see chapter *4.4 Network Management*.

Behaviour when an error occurs

0 If an error occurs, the device changes to "pre-operational" network state if it was previously in the normal operating state "Operational".

1 No change in the network state when an error occurs.

2 The device changes to the network state "stopped" if an error occurs.

Highest sub-index supported	**1029h**	**0**	UNSIGNED8	const	

E

Name	Index	Sub	Type	Acc.	PDO
Number of the several error behaviours which are configurable at the device. The number depends on the device profile. It must, however, be at least 1 (1029.1 is always defined).					
Communication error	**1029h**	**1**	UNSIGNED8	rw	
Device behaviour in case a communication error occurs.					
profile-specific or manufacturer-specific error	**1029h**	**2** ff.	***	rw / const	

Note:

Sub-index 2 and higher defines device error behaviours which are device-specific or device profile-specific. Their definition and behaviour will generally correspond with the description in chapter *Error* behaviour.

If the measurement system used supports these types of parameters, they are described in chapter *3.5.3 Device profile-specific* parameters.

4.5.4.2. Device identifier (General communication objects)

Object index range: 1000h – 1029h

In this section, the objects which provide device-specific information, such as serial number, device part number or software version, are summarised in the chapter "General communication objects".

A small number of these objects are specifically defined in the device profiles. This is relevant for the following objects:

- Device type 1000h

Name	Index	Sub	Type	Acc.	PDO
Device Type	**1000h**	0	*UNSIGNED32*	ro	

Bit 0-15 contains the device profile, i. e. 019Ah → CiA 410
Bit 16-31 device or device-specific additional information

Note: The meaning of bits 16 to 31 will be individually defined in parts by the device profiles; see chapter *3.5.3 Device profile-specific* parameters.

Name	Index	Sub	Type	Acc.	PDO
Manufacturer device name	**1008h**	0	*STRING*	ro	

Readable device name as a character string, which is generally the model code; i. e. "HTT 124V-F11-016-000".

A "segmented" access is necessary in order to read this object, see chapter *4.6.1.3 SDO Upload (segmented) [read]*.

Name	Index	Sub	Type	Acc.	PDO
Manufacturer hardware version	**1009h**	0	*STRING*	ro	

Name	Index	Sub	Type	Acc.	PDO
Current hardware version number, which corresponds with the series index from the serial number as is printed on the type label → i.e. "1".					
Manufacturer software version	**100Ah**	0	*STRING*	ro	
Current device software with version number, e.g. "Hptco2 V06" A "segmented" access is necessary in order to read this object, see chapter *4.6.1.3 SDO Upload (segmented) [read]*.					
Identity object	**1018h**		*RECORD*		
Each individual device worldwide can be clearly identified using this "Identity object".					
Highest sub-index supported	**1018h**	**0**	UNSIGNED8	const	
The "Identity Object" has 4 device-specific features which, in combination with one another, enable clear identification of the relevant specific device.					
Vendor ID	**1018h**	**1**	UNSIGNED32	ro	
Clear manufacturer identification: 0000 00DAh → HYDAC Electronic GmbH					
Product code	**1018h**	**2**	UNSIGNED32	ro	
Product identification number: HYDAC part number, i. e. 926037					
Revision number	**1018h**	**3**	UNSIGNED32	ro	
Device revision number, as listed in the HYDAC serial number					
Serial number	**1018h**	**4**	UNSIGNED32	ro	
Device serial number; generally the last two numbers subsequent to the revision number of the HYDAC serial number which is printed on the type label.					

4.5.4.3. Storage and restoring (general communication objects)

Object index range: 1010h – 1011h

This chapter summarises the two objects which describe the functions for loading the default settings and for permanent writing of changes to the device storage; see chapter *4.5.1.3 Objects serving as* functions .

The following particularities need to be considered:

i	If the function "Store parameters" has not been carried out, changes to the object contents will be lost in the event of a "Reset Node" or if the power supply has been interrupted.

While reconstructing, the factory settings will be copied into a particular area of the device software, into the non-volatile memory. The current values in the volatile memory (RAM) will **not** be changed for this purpose. A device restart is therefore necessary to activate the reconstructed values.

Name	Index	Sub	Type	Acc.	PDO
Store parameters	**1010h**		*ARRAY*		

In order to store changes permanently, one of the sub entries of the object should be described; see chapter *4.5.1.3 Objects serving as* functions .

The character string "save" is the function activating value for all "store" functions.

When accessing as a *UNSIGNED32* value, the character string "save" will be represented by the numerical value 65766173h.

Caution: When performing the SDO command, please observe the order of the steps, see chapters *2.3 Bit* order and *4.6.1 SDO*.

Byte 4	Byte 5	Byte 6	Byte 7
73h "s"	61h "a"	76h "v"	65h "e"

Name	Index	Sub	Type	Acc.	PDO
Highest sub-index supported	**1010h**	**0**	UNSIGNED8	const	

Number of supported sub entries of the object.

Four different functions for the separate storage of parameter sections are supported.

Name	Index	Sub	Type	Acc.	PDO
Save all parameters	**1010h**	**1**	UNSIGNED32	rw	

Storage without limitation of the parameter section.

Special feature: Changes in "*Node* ID*"* and "*Baud* rate*"* will be maintained when activating this function. For permanent storage of these settings, call up the function "***Save LSS parameters***".

Name	Index	Sub	Type	Acc.	PDO
Save communication parameters	**1010h**	**2**	UNSIGNED32	rw	

Permanently saves all changeable objects from the "communication profile area (1000-1FFF)" to the non-volatile memory of the device.

Name	Index	Sub	Type	Acc.	PDO
Save application parameters	**1010h**	**3**	UNSIGNED32	rw	

Permanently saves all changeable objects from the "standardised profile area (6000-9FFF)" to the non-volatile memory of the device.

Name	Index	Sub	Type	Acc.	PDO
Save LSS parameters	**1010h**	**4**	UNSIGNED32	rw	

Permanently saves the first section of the changeable objects from the "manufacturer-specific profile area (2000-20FF)" to the non-volatile memory of the device.

Changes to the "*Node* ID*"* and "*Baud* rate*"* are only saved permanently if this function is activated. The change will only become effective after device restart, however.

Restore default parameters	**1011h**		*ARRAY*		

To restore factory settings, this should be written onto one of the sub entries of this object, see chapter *4.5.1.3 Objects serving as functions* .

The character string "load" is the function activating value for all "Restore" functions.

When accessing as a *UNSIGNED32* value, the character string "load" will be represented by the numerical value 64616F6Ch.

Caution: When performing the SDO command, please observe the order of the steps, see chapters *2.3 Bit* order and *4.6.1 SDO*.

Byte 4	Byte 5	Byte 6	Byte 7
0x6C "l"	0x6F "o"	0x61 "a"	0x64 "d"

Highest sub-index supported	**1011h**	**0**	UNSIGNED8	const	

Number of supported sub entries of the object.

Four different functions, which are separated according to parameter sections, are supported for restoring the factory settings.

Restore all default parameters	**1011h**	**1**	UNSIGNED32	rw	

Restoring without limitation of the parameter section.

Special feature: Settings in "*Node* ID*"* and "*Baud* rate*"* will be maintained when activating this function. To restore these settings, call up the function "*Restore LSS default parameters*".

Restore communication default parameters	**1011h**	**2**	UNSIGNED32	rw	

Restores all factory settings from the "Communication profile area (1000-1FFF)" section.

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Name	Index	Sub	Type	Acc.	PDO
Restore application default parameters	**1011h**	**3**	UNSIGNED32	rw	
Restores all factory settings from the "Standardised profile area (6000-9FFF)" section.					
Restore LSS default parameters	**1011h**	**4**	UNSIGNED32	rw	
Restores the factory settings for the first part of the "Manufacturer-specific profile area (2000-20FF)".					

4.5.4.4. Communication parameters (General communication objects)

Object index range: 1000h – 1029h

In this section, the objects which provide information on the device itself or on the device status (e.g. error management) are summarised. In addition, the basic settings for transmission services and functions for permanent storage of settings are contained herein.

Name	Index	Sub	Type	Acc.	PDO
COB-ID SYNC	**1005h**	0	UNSIGNED32	rw	
Message ID for the identification of the synchronous message during synchronous process data transmission; see chapter *4.6.2.2 SYNC*. This message should be assigned a high priority, in order to keep the latency caused by other messages low. **Standard settings:** 80h (128d)					
COB-ID emergency message	**1014h**	0	UNSIGNED32	rw	
Message ID for sending the *EMCY message* (Emergency). If the COB-ID is set via a *SDO command* to a particular CAN-ID, the mechanism for the automatic expansion of the COB-ID by an active Node-ID is deactivated. In this case, the predetermined CAN-ID will always be used for the transmission of an EMCY, regardless of the Node-ID. If the COB-ID is set to = 0, the default settings will become effective again. **Standard settings:** $NODEID+80h.					
Producer heartbeat time	**1017h**	0	UNSIGNED16	rw	
Activate/deactivate heartbeat "Producing" The device is able to send heartbeat messages on a cyclic basis; see chapter *4.4.3 Heartbeat*. **0** No heartbeat messages will be sent **>0** Time interval in [ms] for cyclic heartbeat messages					

E

4.5.4.5. CANopen safety objects

Object index range: 1300h – 13FFh

The devices described in this documentation (see chapter *1.1 Scope* of application) do **not** support any **functionally safe communication**.

4.5.4.6. RPDO communication parameter

Object index range: 1400h – 15FFh

This range defines in which way a RPDO (i.e. process data received from the device) will be transmitted.

Whether this measurement system supports RPDO communication is defined by the amount of process data objects in the specified part of this documentation. See chapter *3.5.4.1 Number of the process data objects* supported by the device..

For a general description of the PDO transmission, please see chapter *4.6.2 PDO*.

To change the PDO mapping, a defined process has to be adhered to, see chapter *4.6.2.5 Process flow sequence to change the "PDO mapping"*.

i	The max. amount of possible RPDO is firmly defined by the device, see chapter *3.5.4.1 Number of the process data objects* supported by the device..
i	The first "RPDO communication parameter" has the index 1400, the second one has 1401 and so on. The following section describes the first object. The structure of possible additional objects corresponds with this description.

Name	Index	Sub	Type	Acc.	PDO
RPDO communication parameter 1	**1400h**		*RECORD*		
Each available RPDO has its own structure for the definition of its individual transmission type.					
Highest sub-index supported	**1400h**	**0**	UNSIGNED8	const	
The "RPDO communication parameter" object supports max. 5 (CiA 301 max: 6) different sub entries which do not all have to be defined.					
COB-ID	**1400h**	**1**	UNSIGNED32	rw	

COB-ID for the calculation of the operating CAN-ID under which the RPDO will be accepted and received.

If the COB-ID is set via a *SDO command* to a particular CAN-ID, the mechanism for the automatic expansion of the COB-ID by an active Node-ID is deactivated. In this case, the predetermined CAN-ID will always be used for the transmission of an RPDO, regardless of the Node-ID. If the COB-ID is set to = 0, the default settings will become effective again.

By setting Bit 31 of the COB-ID, the RPDO can be deactivated. It will no longer be received afterwards; i. e. $NODEID+80000200h.

Bit 31	Bit 30	Bit 29	Bit 28	Bit 27	Bit 26	Bit 25	Bit 24	Bit 23	Bit 22	Bit 21	Bit 20	Bit 19	Bit 18	Bit 17	Bit 16	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Invalid	Reserved	Extended																													
0	0	0	00000h																		11 Bit CAN-ID										
0	0	1	29 Bit CAN-ID																												

Extended	**0: 11 Bit CAN-ID**	1: 29 Bit CAN-ID
Invalid	**0: PDO is active**	1: PDO is not active

Name	Index	Sub	Type	Acc.	PDO
Standard settings: $NODEID+200h.					
Transmission type	**1400h**	**2**	UNSIGNED8	rw	

This parameter defines the transmission type.

0	acyclic synchronous
1	synchronous with each *SYNC*
2	synchronous with every 2nd SYNC
n - 240	synchronous with every nth SYNC
254	event-controlled manufacturer-specific event options
255	event-controlled device-specific event options

For 254 and 255, see chapters *4.6.2.1 Event driven* and *3.6.3 Device-specific PDO events*.

Standard default settings: 254

Name	Index	Sub	Type	Acc.	PDO
Inhibit time	**1400h**	**3**	UNSIGNED16	rw	

Minimum delay for the RPDO processing as a multiple of 100 µs. The value 0 will deactivate this blocking period.

The value may be device-specific; see chapter *3.5.1 Configuration* parameters.

Name	Index	Sub	Type	Acc.	PDO
Event timer	**1400h**	**5**	UNSIGNED16	rw	

Monitoring interval for RPDO processing. When the timer is set (> 0), the time between two RPDOs will be measured and reported to the device software, if exceeded.

The time is defined as a multiple of 1 ms.

4.5.4.7. RPDO mapping parameter

Object index range: 1600h – 17FFh

This range defines which actual process value parameter objects will be transmitted within one of the available RPDOs.

Whether this measurement system supports RPDO communication is defined by the amount of process data objects in the specified part of this documentation. See chapter *3.5.4.1 Number of the process data objects* supported by the device..

Objects which are used for transmission are indicated by the object characteristic "*PDOMapping*" = 1 (TRUE), see chapter *4.5.1.4 Objects serving* as *process data content.*

For a description of the PDO transmission, please see chapter *4.6.2 PDO*.

For a detailed description of the "PDO mapping" structure, see chapter *4.6.2.3 PDO Mapping*.

To change the PDO mapping, a defined process has to be adhered to, see chapter *4.6.2.5 Process flow sequence to change the "PDO mapping"*.

The max. amount of possible RPDO is firmly defined by the device, see chapter *3.5.4.1 Number of the process data objects* supported by the device..

The first "RPDO mapping parameter" has the index 1600, the second one has 1601 and so on. The following section describes the first object. The structure of possible additional objects corresponds with this description.

Name	Index	Sub	Type	Acc.	PDO
RPDO mapping parameter 1	**1600h**		*RECORD*		

Each available RPDO has its own structure for the definition of the process value parameter objects to be transmitted by this PDO.

The "RPDO mapping parameter" object usually supports up to 8 + 1 different sub entries. The first entry defines the amount of valid sub-entries, while the following entries define the values to be transmitted subsequently (process value parameters).

Number of mapped objects in PDO	**1600h**	**0**	UNSIGNED8	rw	

The first entry defines the amount of valid sub entries, the following sub entries defines the values (process value parameters) which shall be transmitted by the corresponding RPDO.

If the content of this object is set to = 2, for instance, the first two of the subsequent subindex objects must have a valid *Process value parameter object reference*. In that structure, the entries need to be filled in a strictly sequential order and without leaving any gaps.

If the object is set to = 0 (1600.0 = 0) the transmission of the RPDO is deactivated.

Important note: Before there can be changes to the PDO mapping, the PDO transmission has to be deactivated; see chapter *4.6.2.5 Process flow sequence to change the "*PDO mapping".

E

Name	Index	Sub	Type	Acc.	PDO
1st object to be mapped	**1600h**	**1**	*UNSIGNED32*	rw	

First reference object for the definition of the process value parameter object which will be transmitted by the RPDO; "*Number of mapped objects*" >= 1.

The byte position in the *Data block of the CAN message* of the RPDO is byte 0. The required data length in the CAN data block depends on the *Data length of the data type* of the referenced process value parameter object.

Which process value parameter object will actually be referenced, is encoded in the object content. That is why it is subdivided into 3 sections:

1600h **1**	*UNSIGNED32* [32 Bit]		
Object reference	Object index [16 Bit]	sub-index [8 Bit]	Data length [8 Bit]
Example	5200	01	10h

Example: **1600.1 = 52000110h** → 5200.1 [*INTERGER16*]

Name	Index	Sub	Type	Acc	PDO
Velocity values X	**5200h**	**1**	INTEGER16	rww	RP

Graphic representation of that context, see chapter *4.6.2.4 Overview diagram PDO mapping*.

2nd object to be mapped	**1600h**	**2**	UNSIGNED32	rw	

"*Number of mapped objects*" >= 2; Reference to the second process value parameter object to be transmitted.

The position in the *Data block of the CAN message* of the RPDO is calculated depending on the previous object.

nth object to be mapped	**1600h**	**n: [3, 7]**	UNSIGNED32	rw	

"*Number of mapped objects*" >= n; Reference to the n-th process value parameter object to be transmitted.

The position in the *Data block of the CAN message* of the RPDO is calculated depending on the previous object.

8th object to be mapped	**1600h**	**8**	UNSIGNED32	rw	

"*Number of mapped objects*" = 8; Reference to the eighth process value parameter object to be transmitted.

The position in the *Data block of the CAN message* of the RPDO is calculated depending on the previous object.

4.5.4.8. TPDO communication parameter

Object index range: 1800h – 19FFh

This range defines in which way a TPDO (i.e. process data sent by the device) will be transmitted.

For a general description of the PDO transmission, please see chapter *4.6.2 PDO*.

To change the PDO mapping, a defined process has to be adhered to, see chapter *4.6.2.5 Process flow sequence to change the "*PDO mapping".

> The max. amount of possible TPDO is firmly defined by the device, see chapter *3.5.4.1 Number of the process data objects* supported by the device..

> The first "TPDO communication parameter" has the index 1800, the second one has 1801 and so on. The following section describes the first object. The structure of possible additional objects corresponds with this description.

Name	Index	Sub	Type	Acc.	PDO
TPDO communication parameter 1	**1800h**		*RECORD*		
Each available TPDO has its own structure for the definition of its individual transmission type.					
Highest sub-index supported	**1800h**	**0**	UNSIGNED8	const	
The "TPDO communication parameter" object supports max. 5 (CiA 301 max: 6) different sub entries which do not all have to be defined.					

Name	Index	Sub	Type	Acc.	PDO
COB-ID	**1800h**	**1**	UNSIGNED32	rw	

COB-ID for the calculation of the operating CAN-ID under which the TPDO will be sent.

If the COB-ID is set via a *SDO command* to a particular CAN-ID, the mechanism for the automatic expansion of the COB-ID by an active Node-ID is deactivated. In this case, the predetermined CAN-ID will always be used for the transmission of a TPDO, regardless of the Node-ID. If the COB-ID is set to = 0, the default settings will become effective again.

By setting Bit 31 of the COB-ID, the TPDO can be deactivated. It will no longer be transmitted afterwards; i. e. $NODEID+C0000180h.

Bit 31	Bit 30	Bit 29	Bit 28	Bit 27	Bit 26	Bit 25	Bit 24	Bit 23	Bit 22	Bit 21	Bit 20	Bit 19	Bit 18	Bit 17	Bit 16	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Invalid	No RTR	Extended																													
0	1	0	00000h																		11 Bit CAN-ID										
0	1	1	29 Bit CAN-ID																												

Extended	**0: 11 Bit CAN-ID**	1: 29 Bit CAN-ID
No RTR	0: RTR permitted	**1: RTR access not permitted** (automatically set when writing)
Invalid	**0: PDO is active**	1: PDO is not active

Standard settings: $NODEID+40000180h.

Note: RTR communication should no longer be used according to CiA and is therefore deactivated and can no longer be set.

Transmission type	**1800h**	**2**	UNSIGNED8	rw	

This parameter defines the transmission type.

0	acyclic synchronous Internal signal processing synchronous with *SYNC*; Transmission of the message synchronous with SYNC.
1	Internal signal processing synchronous with *SYNC*; Transmission of the message synchronous with any *SYNC*.
2	… Transmission of the message synchronous with any second *SYNC*.
n - 240	Transmission of the message synchronous with any n^{th} *SYNC*.
254	(FEh) Event-controlled manufacturer-specific event options.
255	(FFh) Event-controlled device-specific event options.
	For 254 and 255, see chapters *4.6.2.1 Event driven* and *3.6.3 Device-specific PDO events*.

Standard default settings: 254

Name	Index	Sub	Type	Acc.	PDO
Inhibit time	**1800h**	**3**	UNSIGNED16	rw	

In the case of an active "Transmission type" 254 or 255, this parameter defines the minimum waiting delay before a TPDO is sent after an event has occurred. The amount of sent TPDO can consequently be reduced in the case of a frequently occurring event.

0	The value 0 deactivates the minimum waiting delay.
>0	The time is defined as a multiple of 100 µs.

Name	Index	Sub	Type	Acc.	PDO
Event timer	**1800h**	**5**	UNSIGNED16	rw	

In the case of an active "Transmission type" 254 or 255, this parameter defines the time interval for triggering a "timer event" which leads to the TPDO being sent.

If the device has device-specific events, the TPDO will be sent at the latest by the expiry of that time period, if no other events occur; see chapters *4.6.2.1 Event driven* and *3.6.3 Device-specific PDO events*.

0	Sending of the TPDO is deactivated.
>0	The event interval as a multiple of 1 ms.

4.5.4.9. TPDO mapping parameter

Object index range: 1A00h – 1BFFh

This range defines which actual process value parameter objects will be transmitted within one of the available TPDOs.

Objects which are used for transmission are indicated by the object characteristic "*PDOMapping*" = 1 (TRUE), see chapter *4.5.1.4 Objects serving as* process data content*.*

For a description of the PDO transmission, please see chapter *4.6.2 PDO*.

For a detailed description of the "PDO mapping" structure, see chapter *4.6.2.3 PDO Mapping*.

To change the PDO mapping, a defined process has to be adhered to, see chapter *4.6.2.5 Process flow sequence to change the "*PDO mapping".

The max. amount of possible TPDO is firmly defined by the device, see chapter *3.5.4.1 Number of the process data objects* supported by the device..

The first "TPDO mapping parameter" has the index 1A00, the second one has 1A01 and so on. The following section describes the first object. The structure of possible additional objects corresponds with this description.

Name	Index	Sub	Type	Acc.	PDO

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Name	Index	Sub	Type	Acc.	PDO
TPDO mapping parameter 1	**1A00h**		*RECORD*		

Each available TPDO has its own structure for the definition of the process value parameter objects to be transmitted by this PDO.

The "TPDO mapping parameter" object usually supports up to 8 + 1 different sub entries. The first entry defines the amount of valid sub-entries, while the following entries define the values to be transmitted subsequently (process value parameters).

Name	Index	Sub	Type	Acc.	PDO
Number of mapped objects in PDO	**1A00h**	**0**	UNSIGNED8	rw	

The value of this object defines how many of the subsequent sub entries are valid, which means how many process parameter objects will be transmitted in this TPDO.

If the content of this object is set to = 2, for instance, the first two of the subsequent sub-index objects must have a valid *Process value parameter object reference*. In that structure, the entries need to be filled in a strictly sequential order and without leaving any gaps.

If the object is set to = 0 (1A00.0 = 0), the transmission of the TPDO is deactivated.

Important note: Before there can be changes to the PDO mapping, the PDO transmission has to be deactivated; see chapter *4.6.2.5 Process flow sequence to change the "*PDO mapping".

E

Name	Index	Sub	Type	Acc.	PDO
1st object to be mapped	**1A00h**	**1**	*UNSIGNED32*	rw	

First reference object for the definition of the process value parameter object which will be transmitted by the TPDO; "*Number of mapped objects*W" >= 1.

The byte position in the *Data block of the CAN message* of the TPDO is byte 0. The required data length in the CAN data block depends on the *Data length of the data type* of the referenced process value parameter object.

Which process value parameter object will actually be referenced, is encoded in the object content. That is why it is subdivided into 3 sections:

1A00h	**1**	*UNSIGNED32* [32 Bit]		
Object reference		Object index [16 Bit]	sub-index [8 Bit]	Data length [8 Bit]
Example		6010	00	10h

Example: **1A00.1 = 60100010h** → 6010.0 [*INTERGER16*]

Name	Index	Sub	Type	Acc	PDO
Slope long16	**6010h**	0	INTEGER16	ro	TP

1A00.1 = 60040020h → 6004.0 [*INTERGER32*]

Name	Index	Sub	Type	Acc	PDO
Position value	**6004h**	0	INTEGER32	ro	TP

Graphic representation of that context, see chapter *4.6.2.4 Overview diagram PDO mapping*.

2nd object to be mapped	**1A00h**	**2**	UNSIGNED32	rw	

"*Number of mapped objects*" >= 2; Reference to the second process value parameter object to be transmitted.

The position in the *Data block of the CAN message* of the TPDO is calculated depending on the previous object.

nth object to be mapped	**1A00h**	**n: [3, 7]**	UNSIGNED32	rw	

"*Number of mapped objects*" >= n; Reference to the n-th process value parameter object to be transmitted.

The position in the *Data block of the CAN message* of the TPDO is calculated depending on the previous object.

8th object to be mapped	**1A00h**	**8**	UNSIGNED32	rw	

"*Number of mapped objects*" = 8; Reference to the eighth process value parameter object to be transmitted.

The position in the *Data block of the CAN message* of the TPDO is calculated depending on the previous object.

4.5.4.10. NMT master objects

Object index range: 1F80h – 1F89h

The objects defining the network behaviour of the devices are described herein.

Name	Index	Sub	Type	Acc.	PDO
NMT startup	**1F80h**	0	UNSIGNED32	rw	

Defining the start behaviour of the device; see also chapter *4.4 Network Management*.

Bit 2 0: Device remains in the *"Pre-Operational"* state after successful initialisation and waits for a *"Start Node" command*.

1: Device automatically switches to "Operational" state after successful initialisation.

Note: This behaviour does not correspond with the definition in the CiA 302 Part 2, the logic has been inverted with respect to the behaviour described therein.

Bit 3 1: always needs to be set.

Bit x 0: all further bits may not be set.

0000 0008h → 8d device waits in "Pre-Operational" (common default settings)

0000 000Ch → 12d Device automatically switches to "Operational" state.

4.5.5. Manufacturer-specific profile area

Object index range: 2000 – 5FFF

Manufacturer-specific objects are usually also device-specific. This chapter describes objects which are normally always supported by the devices.

4.5.5.1. Node-ID and Baud rate

The management of the two most important CANopen device settings is unfortunately not clearly specified in the CiA 301. The most common implementation used by HYDAC Electronic GmbH is described below.

> Some older devices and devices which are part of the ETS 1000 and ETS 4100 series by HYDAC ELECTRONIC have functions for the configuration of the Node-ID and Baud rate which may differ from the functions in the description below.
>
> Possible differences are described in the device-specific part of the documentation in chapter *3.5.2 Manufacturer-specific configuration* parameters.

In addition, the devices provide the configuration of the Node-ID and Baud rate via the LSS protocol, see chapter*4.7 Layer setting services (LSS) Protocol*.

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Name	Index	Sub	Type	Acc.	PDO
Node ID	**2001h**		*ARRAY*		

Object for the device address management; see chapter *4.4 Network Management*.

The standard setting of the device address is described in chapter *3.1.1 CANopen default settings.*

Note:
Some of the HYDAC ELECTRONIC sensors (e.g. pressure or temperature) may still support an earlier implementation of the Node-ID object 2001h. If the implementation should differ, please see chapter *3.5.2 Manufacturer-specific configuration parameters*.

Name	Index	Sub	Type	Acc.	PDO
Highest sub-index supported	**2001h**	**0**	UNSIGNED8	ro	

For the management of the device address, there are two objects available.

Name	Index	Sub	Type	Acc.	PDO
Active node-ID	**2001h**	**1**	UNSIGNED8	ro	

Currently active device address; read only

Name	Index	Sub	Type	Acc.	PDO
Pending node-ID	**2001h**	**2**	UNSIGNED8	rw	

Desired change of device address

Changes of this entry will not take effect until they have been saved into the non-volatile memory (see chapters ***Store parameters*** and ***Save LSS parameters***) and the device has been restarted *"Reset Node" command*or its power supply has been cut.

The values of the objects 2001.1 and 2001.2 are identical under normal operation. Should there be a request for a new device address when the changes have not yet become active, the two objects will be assigned different values.

Name	Index	Sub	Type	Acc.	PDO
Baud rate	**2002h**		*ARRAY*		

Object for the device Baud rate; see chapter *4.2.5 Transmission* speed.

The values of this object correspond with the DS 305 "Layer Setting Services and Protocols".

0	1000 kbit/s	
1	800 kbit/s	
2	500 kbit/s	
3	250 kbit/s	
4	125 kbit/s	
5	100 kbit/s	CiA 305: reserved (not supported by every device)
6	50 kbit/s	
7	20 kbit/s	
8	10 kbit/s	

The standard configuration of the Baud rate is described in chapter *3.1.1 CANopen default* settings.

Note:
Some of the HYDAC ELECTRONIC sensors (e.g. pressure or temperature) may still support an earlier implementation of the Baud rate object 2002h. If the implementation

Name	Index	Sub	Type	Acc.	PDO
should differ, please see chapter *3.5.2 Manufacturer-specific configuration* parameters.					
Highest sub-index supported	**2002h**	**0**	UNSIGNED8	ro	
For the management of the Baud rate, there are two objects available.					
Active baudrate	**2002h**	**1**	UNSIGNED16	ro	
Currently active Baud rate; read only					
Pending baudrate	**2002h**	**2**	UNSIGNED16	rw	
Desired change of Baud rate Changes of this object will not take effect until they have been saved into the non-volatile memory (see chapters *Store parameters* and *Save LSS parameters*) and the device has been restarted, *"Reset Node" command* or its power supply has been cut. The values of the objects 2002.1 and 2002.2 are identical under normal operation. Should there be a request for a new Baud rate when the changes have not yet become active, the two objects will be assigned different values.					
Checksum	**2010h**	0	UNSIGNED32	ro	
The checksum of the current device software.					

4.5.5.2. Additional manufacturer-specific measurement channels

Some devices offer additional measurement channels which complete the standard measurement variables, such as pressure in a pressure sensor, which increases the benefit of the device. Additional manufacturer-specific measurement channels are able to provide "real" measurement signals with a defined specification in the data sheet, such as accuracy or temperature coefficient, but also internal signals, such as the device temperature.

> The device-specific section of the documentation also provides information on whether a device has manufacturer-specific measurement channels or which measured variable corresponds to which "sub-index" or which channel settings are actually supported by the respective measurement channel, see chapter *3.5.5 Additional manufacturer-specific measurement* channels.

The process values of the additional manufacturer-specific measurement channels can be transferred via a *TPDO*.

This type of measurement channel will, however, either not be supported at all or at least not fully supported by each device. This means that the objects listed below may only be partly available or not at all. If these objects, however, are provided by a device, their significance corresponds with the description below. The function principle of the objects is based on the device profile CiA 404.

The table shows an example of a device with **one** additional, manufacturer-specific measurement channel. In devices with several channels, only the amount of "sub-indices" is

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higher – 3610.1 would represent the first channel, 3610.2 would be the second channel, and so on.

To enable easy further processing, the signal value of an additional manufacturer-specific measurement channel will be provided multiple times and simultaneously as *Process value*, in objects with varying *Data types*:

- **36**xy.z *REAL32* → first signal value: **36**10.1 …
- **37**xy.z *INTEGER16* → first signal value: **37**10.1 …
- **39**xy.z *INTEGER32* → first signal value: **39**10.1 …

The configuration parameter options are shown using the REAL32-Objects (**36**xy.z). The object structure of the other data types corresponds with the structure of this data type. The objects may partly be omitted, however.

Name	Index	Sub	Type	Acc.	PDO
MS input MV	**3610**		*ARRAY*		
The object provides the signal values/measured values of the additional manufacturer-specific measurement channels.					
Highest sub-index supported	**3610**	**0**	UNSIGNED8	ro	
The number of "sub-index" objects corresponds with the number of the manufacturer-specific measurement channels provided by the device.					
MS input MV 1	**3610**	**1**	REAL32	ro	TP
Current signal value of the first manufacturer-specific device measurement channel.					
MS input MV 2	**3610**	**2**	REAL32	Ro	TP
Example of a possible second manufacturer-specific measurement channel.					
MS input scaling 1 MV	**3611**		*ARRAY*		
Lower measuring range limit of an additional manufacturer-specific measurement channel. The value indication is represented in the unit of the measurement channel, i.e.: -40 -40 °C as the lower fluid temperature measuring range 0 0 bar as the lower pressure measuring range					
Highest sub-index supported	**3611**	**0**	UNSIGNED8	ro	
Corresponds with the number of the manufacturer-specific device measurement channels.					
MS input scaling 1 MV 1	**3611**	**1**	REAL32	ro	
Lower measuring range limit of the first additional manufacturer-specific measurement channel. … further "sub-index" entries possible					
MS input scaling 2 MV	**3612**		*ARRAY*		

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Name	Index	Sub	Type	Acc.	PDO
Upper measuring range limit of an additional manufacturer-specific measurement channel. The value indication is represented in the unit of the measurement channel, i.e.: 100 +100 °C as the upper fluid temperature measuring range 600 600 bar as the upper pressure measuring range					
Highest sub-index supported	**3612**	**0**	UNSIGNED8	ro	
Corresponds with the number of the manufacturer-specific device measurement channels.					
MS input scaling 2 MV 1	**3612**	**1**	REAL32	ro	
Upper measuring range limit of the first additional manufacturer-specific measurement channel. … further "sub-index" entries possible					
MS status	**3613**		*ARRAY*		
Status information for an additional manufacturer-specific measurement channel. The sense of a status word depends on the device.					
Highest sub-index supported	**3613**	**0**	UNSIGNED8	const	
Corresponds with the number of the manufacturer-specific device measurement channels.					
MS status 1	**3613**	**1**	UNSIGNED8	ro	TP
Status information for the first additional manufacturer-specific measurement channel. … further "sub-index" entries possible					
MS decimal digits MV	**3614**		*ARRAY*		
Number of decimals of the additional manufacturer-specific measurement channel.					
Highest sub-index supported	**3614**	**0**	UNSIGNED8	const	
Corresponds with the number of the manufacturer-specific device measurement channels.					
MS decimal digits MV 1	**3614**	**1**	UNSIGNED8	rw	
Number of decimals of the first additional manufacturer-specific measurement channel. … further "sub-index" entries possible					
MS input offset	**3615**		*ARRAY*		
Zero-offset (value offset) of the additional manufacturer-specific measurement channel.					
Highest sub-index supported	**3615**	**0**	UNSIGNED8	const	

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Name	Index	Sub	Type	Acc.	PDO
Corresponds with the number of the manufacturer-specific device measurement channels.					
MS input offset 1	**3615**	**1**	REAL32	rw	
Zero-offset of the first additional manufacturer-specific measurement channel. … further "sub-index" entries possible					
MS autozero	**3616**		*ARRAY*		
Use the current signal value of the additional manufacturer-specific measurement channel as offset. When performing a default offset adjustment, the content of the object *"MS input offset*" will be set to the current, corresponding signal value (current content of the object "*MS input MV*") at the moment of activating this object. This object is a *Function object* and is activated via writing the *Character string* "zero" (6F72657Ah); see chapter *4.5.1.3 Objects serving as* functions .					
Highest sub-index supported	**3616**	**0**	UNSIGNED8	const	
Corresponds with the number of the manufacturer-specific device measurement channels.					
MS autozero	**3616**	**1**	UNSIGNED32	wo	
Activate automatic zero-offset (value offset) of the first additional manufacturer-specific measurement channel. … further "sub-index" entries possible					
MS physical unit MV	**3617**		*ARRAY*		
Inquire physical unit of the additional manufacturer-specific measurement channel. The unit will be provided as an SI unit according to CiA 303-2. Standard physical units are: 004E0000h bar 00AB0000h PSI 002D0000h °C 00AC0000h °F					
Highest sub-index supported	**3617**	**0**	UNSIGNED8	const	
Corresponds with the number of the manufacturer-specific device measurement channels.					
MS physical unit MV 1	**3617**	**1**	UNSIGNED32	ro	
Inquire physical unit of the first additional manufacturer-specific measurement channel. … further "sub-index" entries possible					

4.5.6. Standardized profile area

Object index range: 6000h – 9FFFh

For a general description of a device profile, please read the corresponding publication by CiA (i.e. "CiA 410 Device profile for inclinometer“).

See chapter *3.1.2 Device* profile of the device-specific section in the documentation to learn which device profile is supported by the device in use.

If a device should show deviations from a device profile, the explanation can be found in chapter *3.5.3 Device profile-specific* parameters.

4.5.7. EDS Electronic Data Sheet

The "Electronic data sheet", abbreviation: "EDS file" / "EDS", is a machine readable description of the OD, see chapter *4.5 The Object* Dictionary. All objects supported by the device are listed herein. Each object has a multi-line entry for its description.

In the headline of the EDS, general information is given on the file itself and on the device which is described by the file.

The individual objects are listed in blocks and will always be launched by an object index. Each index has its own description block. If the index has several different sub entries (sub-index), these also have their own description block.

4.5.7.1. Description of the most important EDS entries

The most important entries and the related most important meanings of an EDS file are listed below.

Identifier	Content	Description
[<objectindex>]	[1000]	Object index of the following description block; [1000] → *DeviceType*. see chapter *4.5.1.1°Addressing*
	[1003sub4]	→ 1003.4 Sub-entry of the object "*Pre-defined error field*"
ParameterName		Object name
ObjectType		Object property This entry defines which property this object entry has.
	07h	VAR Object is a variable
	08h	*ARRAY* Object is a data structure of the Array type and therefore consists of further entries having the same data type.
	09h	*RECORD* Object is a data structure of the Record/Structure type and therefore, it consists of further entries having different data types.

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Identifier	Content	Description	
DataType		Object data type In objects of the "ObjectType = 7h", the data type defines how the object is going to be stored in the memory. This information is important for reading and writing the object; see chapter *4.6.1 SDO*.	
	0002h	*INTERGER8*	signed integer 8 bits
	0003h	*INTERGER16*	signed integer 16 bit
	0004h	*INTERGER32*	signed integer 32 bit
	0005h	*UNSIGNED8*	unsigned integer 8 bits
	0006h	*UNSIGNED16*	unsigned integer 16 bits
	0007h	*UNSIGNED32*	unsigned integer 32 bit
	0008h	*REAL32*	Floating point 32 bits
	0009h	*STRING*	Character string
AccessType	ro, rw, rwr, rww, wo, const	Object access authorisation see chapter *4.5.1.2 Object* access types	
DefaultValue		Object content at delivery (pre-configuration)	
PDOMapping	0 / 1	Can the object be used as a process data value? see chapters *4.5.1.4 Objects serving as* process data content and *4.6.2.3 PDO Mapping*	
BaudRate_xxx _10 .. _1000	0 / 1	Definition of the *Baud rates* supported by the device. If the actual value "= 1" (TRUE) is set, the Baud rate will be set accordingly.	
NrOfRXPDO	0 … 64	Max number of *RPDO objects* supported by the device.	
NrOfTXPDO	0 … 64	Max number of *TPDO Objects* supported by the device.	
LSS_Supported	0 / 1	Is the *LSS Protocol* supported by the device? "= 1" (TRUE) the device supports LSS	

4.5.7.2. EDS file example

The following is an extract of an EDS file. The individual object 1001.0 "*Error register"* and the *RECORD* object 1018 "*Identity object"* are listed as object examples.

```
[FileInfo]
```

```
FileName=HE-926037-0008.eds
…
[DeviceInfo]
VendorName=HYDAC ELECTRONIC GMBH
ProductNumber=926037
…
[1001]
ParameterName=Error register
ObjectType=0x7
DataType=0x5
AccessType=ro
PDOMapping=1
…
[1018]
ParameterName=Identity object
ObjectType=0x9
[1018sub0]
ParameterName=Highest sub-index supported
ObjectType=0x7
DataType=0x5
AccessType=const
DefaultValue=4
[1018sub1]
ParameterName=Vendor-ID
ObjectType=0x7
DataType=0x7
AccessType=ro
DefaultValue=218
```

4.6. Application data

CANopen provides different types of data communication. Not every one of these communication types will be available in each operation state; see chapter *4.4.1 Overview of* network states.

4.6.1. SDO

SDO, abbr. for "**S**ervice **d**ata **o**bject", enables direct access to the individual objects in the OD; see chapter *4.5 The Object* Dictionary.

It is possible to have read access and write access to objects. During access, the object address serves as an indicator of which object the access should be given to; see chapter *4.5.1.1 Addressing*.

Whether access will or will not be permitted to a particular object can be determined from the object authorisation (see chapter *4.5.1.2 Object* access types) and from the current operation status of the device (see chapter *4.4.1 Overview of* network states).

The data type of the object (see chapter *4.5.7 EDS Electronic Data Sheet* and *DataType*) controls the process of the SDO communication. All objects whose data type is 32 bits and shorter can be read or written to directly with a single SDO command "expedited" , i.e. *INTEGER32* or *REAL32*. Objects whose data type is longer than 32 bit have to be read or written to via a sequence of interrelated commands "segmented".

For the SDO, the Client/Server access is used as a communication type, see chapter *4.3.5.3 Request – Response*. The server is always the network participant whose objects will be accessed - which is the device to write to in this case. The client is usually a higher-level control unit intending to parameterise or configure the device, for instance.

The client communicates a "request" command to the server, saying what it is intending to do and the server always responds by sending a "response" command, indicating whether the access has been successful or if an error has occurred; see chapter *4.6.1.5 SDO abort transfer (abort)*.

4.6.1.1. Structure of the SDO command

Below please find a description of the general structure of all SDO messages. The commands depend on the access type used.

> The particular COB-ID of the SDO corresponds to the "Pre defined Connection Set" defined in the CiA 301 and cannot be altered.

In the below examples, Node-ID = 1 will always be used on the server side (device).

Field name	**Content**	**Meaning**
COB-ID	600h + Node-ID	COB-ID of the SDO-request (Client→Server) [Tx: ECU → Device] The CAN-ID is calculated during operation from the basic CAN-ID and the Node-ID. Example: Node-ID = 1; 600h + 1h = 601h
COB-ID	580h + Node-ID	COB-ID of the SDO-response (Server→Client) [Rx: Device → ECU] Example: Node-ID = 1; 580h + 1h = 581h
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code The command code is crucial for the definition of the data communication process. The command word is bit-encoded and indicates the function, the error state and in parts the amount of useful data in the current message.
BYTE 1, 2	Index	Object index of the object to be accessed; see *4.5.1.1 Addressing* and *2.3 Bit* order. Data type: *UNSIGNED16*
BYTE 3	Subindex	Sub-index of the sub-entry; if no sub-entry exists, this entry will be set to 0. Data type: *UNSIGNED8*
BYTE 4 - 7	Data	Useful data, error information or 0

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Command	Index		Sub index	Data			
	Low-byte	High-byte					

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4.6.1.2. SDO Upload (expedited) [read]

If the client (control) intends to read an object from the server (device), this access can be initiated using the "SDO upload request" command.

For this purpose, the client transfers the *Object address* it intends to read and receives the data or an error message which has been read from the object, in return.

The response from the server may vary, however, depending on the data length of the object to be read out. If the **data length is <= 32** Bit, the command processing will take place in the "**expedited**" mode, i.e. the response from the server directly contains the data of the requested object, as explained below.

If the **data length** of the object to be read out is **> 32 bits**, the communication is carried out in the so-called "**segmented**" mode. The distinction is made via the command code of the "server response"; see chapter *4.6.1.3 SDO Upload (segmented) [read]*.

When showing the object address or the data on the data section of the message, the *Bit order* has to be adhered to.

The example shows an SDO read access to the object 1018.2 "***Product code***". The addressed object is a *UNSIGNED32* value and can therefore be read out in the "expedited" mode. The content of the object is the part number of the device.

- Part number = 926037d → E2155h.

- CMD SDO Command code
- IdxLB Object **index** **L**ow-**B**yte (Byte 1, 2: *UNSIGNED16)*
- IdxHB Object**index** **H**igh-**B**yte
- SIdx Object-**Sub**in**dex**

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	IdxLB	IdxHB	SIdx	Data 1	Data 2	Data 3	Data 4
601h Tx	**40h**	18h	10h	02h	00h	00h	00h	00h
581h Rx	**43h**	18h	10h	02h	55h	21h	0Eh	00h

SDO command codes (CMD) **SDO Upload** (expedited) [read]

Command	Direction	Description
40h	Request	Reading out object from given index
4Fh	Response	1 byte has been read out successfully
4Bh	Response	2 byte has been read out successfully
47h	Response	3 byte has been read out successfully
43h	Response	4 byte has been read out successfully
41h	Response	Object is readable, but its data length is longer than 32 bits (4 Bytes).

Command	Direction	Description
		see chapter *4.6.1.3°SDO Upload (segmented) [read]*
80h	Response	Errors, see chapter*4.6.1.5 SDO abort transfer (abort)*

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4.6.1.3. SDO Upload (segmented) [read]

A few of the objects of the devices will be represented by data types of more than 32 Bits of length. These objects often contain *STRING variables*. In order to read such an object, a sequence of interrelated SDO commands is required. Each step of the sequence always follows the "*Request – Response"* concept of data communication. This process is also referred to as the SDO "segmented" upload.

The sequence will be initiated by a standard read request, see chapter *4.6.1.2 SDO Upload (expedited) [read]*. The server recognises if the object to be read has more than 32 bits of data length by means of the *Object address*. This is why it responds to the client using a particular SDO-response, which contains the length of the data of the addressed object in bytes, instead of the read object data. After sending, the server waits for further "requests" from the client to inquire about the data of the addressed object.

The first data block has to be requested explicitly by the client from the server using a "SDO upload segmented request". The server responds using a "SDO upload segmented response" whose command code indicates that either further data needs to be requested, or that the end of the sequence has been reached.

The "SDO upload segmented response" has a structure which deviates from other SDO commands (see chapter *4.6.1.1 Structure of the* SDO command). It does not contain any *Object address*. It only contains the command code and the useful data.

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Command				Data			

As long as the client has not received any response with a set end code, it should inquire the missing data blocks with another request.

The received data has to be put together at the side of the client to become a combined data block. The order of the incoming data is strictly sequential. Individual data blocks will not be repeated.

The server can terminate the communication using a *SDO abort command*. If an abort has been reported, the inquiry can be reinitiated using a read request.

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A request remains "open" until either:

- the end of the sequence is displayed by the server
- or terminated by the server via an abort
- or reinitiated via a read request.

The below example shows how the object *100A "Manufacturer software* version*"* is to be read out. This object has a *STRING* which may comprise of more than 4 characters (32 Bits).

Note: for a better comparison with the *ASCII encoding*, blanks have been added between the individual characters of the character string which are not a part of the character string's content.

Character string: `H l t c o       V 9 0 . 0 2`

ASCII: `48 6C 75 63 6F 20 20 20 56 39 30 2E 30 32`

The sequence starts with an "upload request" and will be responded to by the server using the code "segmented upload response". The length of the entire data block is reported using OEh → 14d Byte.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	IdxLB	IdxHB	SIdx	Data 1	Data 2	Data 3	Data 4
601h Tx	**40h**	0Ah	10h	00h	00h	00h	00h	00h
581h Rx	**41h**	0Ah	10h	00h	0Eh	00h	00h	00h

In the next step, the client inquires the first block of the data sequence. During this inquiry, however, the object address will not be repeated. The server sends the first 7 characters of the object content "`Hltco  `". The lowest value bit of the response command is not set and shows the client that further data will follow.

601h Tx	**60h**	00h	00h	00h	00h	00h	00h	00h
581h Rx	**00h**	48h	6Ch	74h	63h	6Fh	20h	20h

The client knows from the last response that further data needs to be requested. The amount of data can be checked additionally by the client, as the client is informed of the total data length when receiving the first response.

In order to check the sequence order the client "toggles" Bit 4 of the request command with each new request: 60h → 70h → 60h → 70h … The server itself checks the switching of the bit and reflects the current value to its response (response command code).

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In this particular example, the end of the total data block has been reached after having transferred the second "segmented" response (14 / 7 = 2). All useful data bytes of the response are entirely used and the missing 7 characters will be transferred "`V90.02`". The software version is now complete → "`Hltco    V90.02`".

601h Tx	**70h**	00h	00h	00h	00h	00h	00h	00h
581h Rx	**11h**	20h	56h	39h	30h	2Eh	30h	32h

SDO command codes (CMD) **SDO Upload** (segmented) [read]

Command	Direction	Description
40h	Request	Reading out object from given index see chapter *4.6.1.2°SDO Upload (expedited) [read]*
41h	Response	The object can be read and has the data length transferred in the data field in bytes; data type: *UNSIGNED32*.
60h	Request	First "segmented" upload request and subsequently, after every second request. 60h → 70h → 60h → 70h …
70h	Request	Second "segmented" upload request and following 70h → 60h → 70h …
00h	Response	7 data bytes valid and read, Transmission end not reached; response to request 60h.
10h	Response	7 data bytes valid and read, Transmission end not reached; response to request 70h.
11h	Response	7 data bytes valid and read, Transmission end has been reached; response to request 70h.
X3h	Response	6 data bytes valid and read, Transmission end has been reached; X is 0 (03h) for request 60h and 1 (13h) for request 70h
X5h	Response	5 data bytes valid and read, Transmission end has been reached; X is 0 (05h) for request 60h and 1 (15h) for request 70h
X7h	Response	4 data bytes valid and read, Transmission end has been reached; X is 0 (07h) for request 60h and 1 (17h) for request 70h

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Command	Direction	Description
X9h	Response	3 data bytes valid and read, Transmission end has been reached; X is 0 (09h) for request 60h and 1 (19h) for request 70h
XBh	Response	2 data bytes valid and read, Transmission end has been reached; X is 0 (0Bh) for request 60h and 1 (1Bh) for request 70h
XDh	Response	1 data byte valid and read, Transmission end has been reached; X is 0 (0Dh) for request 60h and 1 (1Dh) for request 70h
80h	Response	Errors, see chapter*4.6.1.5 SDO abort transfer (abort)*

CAN protocol example of reading out the object 1008.

1008.0 Manufacturer device name = "HLT 1300-R2-L06-F11-0100-0250-000"

```
CAN-ID (hex)
|      Direction: Tx (ECU → Device); Rx (Device → ECU)
|      |  Data Length
|      |  |  Data Bytes (hex)
|      |  |  |
+---   +- +  +- -- -- -- -- -- -- --
0601   Tx 8  40 08 10 00 00 00 00 00  SDO upload request
0581   Rx 8  41 08 10 00 21 00 00 00  SDO upload response
                                      segmented,   data   length
21h
0601   Tx 8  60 00 00 00 00 00 00 00  1st segmented request
0581   Rx 8  00 48 4C 54 20 31 33 30  1st segmented response
                                      HLT 130
0601   Tx 8  70 00 00 00 00 00 00 00  2nd segmented request
0581   Rx 8  10 30 2D 52 32 2D 4C 30  2nd segmented response
                                      0-R2-L0
0601   Tx 8  60 00 00 00 00 00 00 00  3rd segmented request
0581   Rx 8  00 36 2D 46 31 31 2D 30  6-F11-0
0601   Tx 8  70 00 00 00 00 00 00 00  4th segmented request
0581   Rx 8  10 31 30 30 2D 30 32 35  100-025
0601   Tx 8  60 00 00 00 00 00 00 00  5th segmented request
0581   Rx 8  05 30 2D 30 30 30 00 00  5th segmented response
                                      End, 5 byte valid
                                      (CMD:X5h)
                                      0-000
```

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4.6.1.4. SDO expedited Download (write)

If the client (control) intends to store a value with 32 bits or lower on the server (device/ measurement system), it will send an "SDO expedited download request" to the server. This request contains the data to be written and will receive a positive or negative confirmation from the server.

When showing the object address or the data on the data section of the message, the *Bit order* has to be adhered to.

In the example, the object 1010.4 "***Save LSS parameters***" will be opened with the character string "save" in order to activate the *Function for storage* of the changes at the OD.

This object is a *UNSIGNED32* value. If an integer value is entered, the character string "save" [ASCII code: 73h 61h 76h 65h] is shown as follows 65766173h – the *Bit order* has to be adhered to.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	IdxLB	IdxHB	SIdx	Data 1	Data 2	Data 3	Data 4
601h Tx	**23h**	10h	10h	04h	73h "s"	61h "a"	76h "v"	65h "e"
581h Rx	60h	10h	10h	04h	00h	00h	00h	00h

In another example, the object 1017 "*Producer* heartbeat time" is activated and set to a repeat rate of 500 ms (1F4h). This object is displayed as a *UNSIGNED16* value.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	IdxLB	IdxHB	SIdx	Data 1	Data 2	Data 3	Data 4
601h Tx	**2Bh**	17h	10h	00h	F4h	01h	00h	00h
581h Rx	60h	17h	10h	00h	00h	00h	00h	00h

Command codes SDO expedited Download (write)

Command	Direction	Description
2Fh	Request	Write 1 byte
2Bh	Request	Write 2 byte
27h	Request	Write 3 byte
23h	Request	Write 4 byte
60h	Response	Object saved successfully
80h	Response	Errors, see chapter*4.6.1.5 SDO abort transfer (abort)*

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4.6.1.5. SDO abort transfer (abort)

If the server detects an error while processing a request command, it will report it to the client sending an "SDO abort transfer" response.

The data field of the SDO command serves to transmit a cancel code (error number). The numeric value is shown as a *UNSIGNED32*and the *Bit order* is to be adhered to.

The command code is always **80h**.

This example shows the attempt to write a value into the object 7654 "*Manufacturer-specific profile area"*. As this object does not exist on that device, the SDO command is cancelled via a cancel response.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	IdxLB	IdxHB	SIdx	Data 1	Data 2	Data 3	Data 4
601h Tx	2Bh	54h	76h	00h	66h	06h	00h	00h
581h Rx	**80h**	54h	76h	00h	**00h**	**00h**	**02h**	**06h**

Abort code	Description
0503 0000h	Toggle bit not alternated.
0504 0000h	SDO protocol timed out.
0504 0001h	Client/server command specifier not valid or unknown.
0504 0002h	Invalid block size (block mode only).
0504 0003h	Invalid sequence number (block mode only).
0504 0004h	CRC error (block mode only).
0504 0005h	Out of memory.
0601 0000h	Unsupported access to an object.
0601 0001h	Attempt to read a write only object.
0601 0002h	Attempt to write a read only object.
0602 0000h	**Object does not exist in the object dictionary.**
0604 0041h	Object cannot be mapped to the PDO.
0604 0042h	The number and length of the objects to be mapped would exceed PDO length.
0604 0043h	General parameter incompatibility reason.
0604 0047h	General internal incompatibility in the device.
0606 0000h	Access failed due to an hardware error.
0607 0010h	Data type does not match, length of service parameter does not match

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Abort code	Description
0607 0012h	Data type does not match, length of service parameter too high
0607 0013h	Data type does not match, length of service parameter too low
0609 0011h	Sub-index does not exist.
0609 0030h	Invalid value for parameter (download only).
0609 0031h	Value of parameter written too high (download only).
0609 0032h	Value of parameter written too low (download only).
0609 0036h	Maximum value is less than minimum value.
060A 0023h	Resource not available: SDO connection
0800 0000h	General error
0800 0020h	Data cannot be transferred or stored to the application ...
0800 0021h	... because of local control.
0800 0022h	... because of the present device state.
0800 0023h	Object dictionary dynamic generation fails or no object dictionary is present.
0800 0024h	No data available

4.6.2. PDO

Process data is the core information in a control system. They identify the nominal and actual values of different participants.

The PDO transfer protocol is implemented according to the *Producer-Consumer* data model.

There are essentially two types of process data which differ from one another with respect to their direction of communication. For CANopen, the direction is always defined from the point of view of the end nodes.

- **TPDO** Process data which is generated by the device (end nodes) and made available to other participants in the network. **T**ransmit **P**rocess **D**ata **O**bject – which means send process data This is how the actual measurement values of a measurement system, for instance, are sent to other network participants as a TPDO.
- **RPDO** Process data generated by a different participant which is sent to the device. **R**eceive **P**rocess **D**ata **O**bject – which means receive process data. This type of process data is often nominal values, but may also represent additional input signals, which can be further processed by the consumer.
- **Number of PDOs** The number of PDOs is device-specific and explained in chapter *3.5.4.1 Number of the process data objects* supported by the device..

The process data for transmission, pre-set by default on delivery of the device, is described in chapter *3.1.1 CANopen default* settings.

Which process data will be transmitted and how is managed by parameters in the OD. This system is referred to as *PDO Mapping*. The devices often are assigned a *Preconfiguration* of the transmitted process data by the manufacturer.

> Without a valid configuration of a PDO, no process data will be sent or received; see chapter *4.6.2.3 PDO Mapping.*

As the configuration can be changed by the user, it is certainly possible that a particular device may send process data which deviates from the standard behaviour.

There are two major setting areas which are important for the transmission of a PDO:

- The parameters defining how the object is going to be transmitted, i.e. cyclically or synchronously.
    - *4.5.4.6 RPDO communication parameter*
    - *4.5.4.8 TPDO communication parameter*
- The parameters defining what information (objects) will be transmitted.
    - *4.5.4.9 TPDO mapping parameter*
    - *4.5.4.7 RPDO mapping parameter*

4.6.2.1. Event driven

In general, there are two ways of transmitting process data:

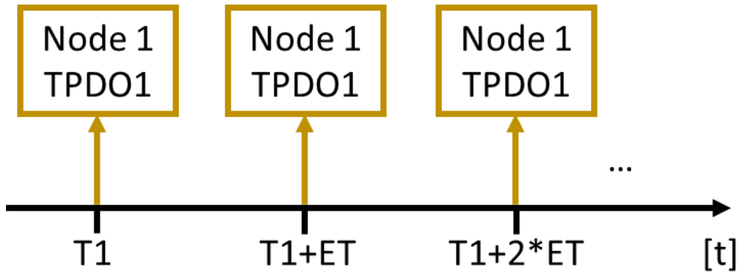
- An event in the device triggers the transmission.
- The device receives a synchronisation message, see chapter *4.6.2.2 SYNC*.

> The use of RTR ("remote frame request") based events is not recommended.

The most common type of event controlled transmission is periodic transmission. This is based on a settable, fixed cycle time, see object "*Event timer*". Which transmission type to use is defined via the "*PDO communication parameter*".

Devices meeting the requirements of a device profile sometimes provide additional event types. For example, the CiA 404 "Device profile for measuring devices" offers the opportunity to trigger the sending of a TPDO when a measured value has been exceeded. If a device offers additional event variants, these are described in chapter *3.6.3 Device-specific PDO events*.

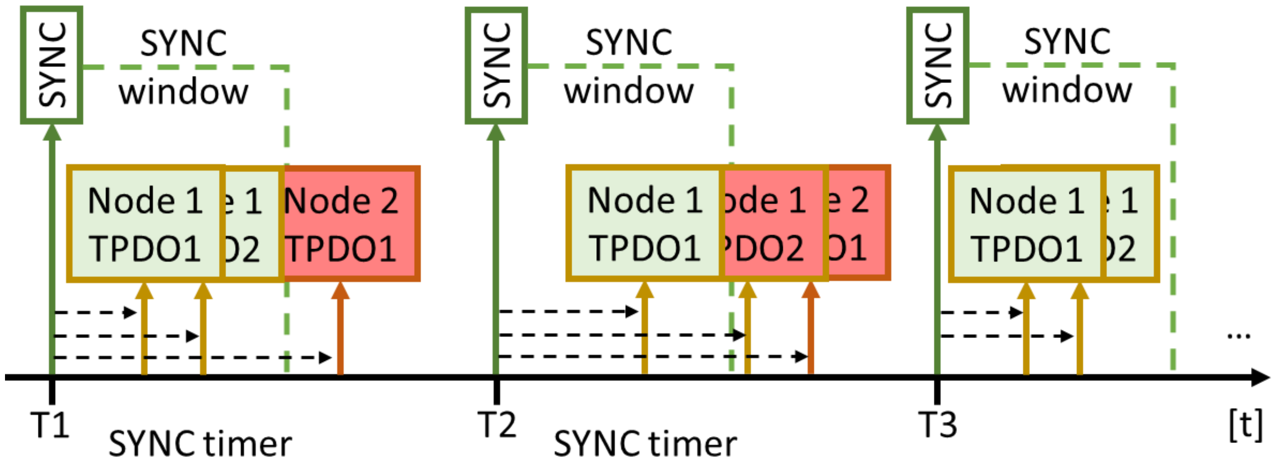
If the event-controlled transmission of the PDO and the *Event timer*(ET) are activated, the PDO will be transmitted after expiry of the "event time" at the latest, if no other device event has occurred.



4.6.2.2. SYNC

For tasks in automation technology, it is often necessary to perform processes synchronously. If, for instance, engine power is to be measured, it is also necessary to measure its speed and torque at the same time. The synchronised transmission of the PDO is one solution for this.

The SYNC protocol is implemented according to the *Master-Device* data model and used for the synchronisation of the *PDO transmission* which works on the basis of this data model itself.



Subsequent to receiving the SYNC message, the SYNC device should start its internal signal processing. After having processed the signal, a PDO will immediately be generated and sent. The SYNC device monitors a time frame within which a received PDO message is valid. Messages received after the time frame has expired will be discarded.

The SYNC processing can be configured via the object "*Transmission type"* from the"xPDO communication parameter" section. Generating a PDO message does not need to be carried out after each SYNC, but can also be defined as a multiple of the SYNC. Via this mechanism, the transmission can be divided into important or informative PDOs.

The usual time intervals for SYNC range within a few 10 ms. For example, a rapidly changing pressure value can be transmitted with every SYNC (e.g. every 10 ms), whereas a slowly changing temperature value can be transmitted every 100 SYNC (100 * 10 ms = 1 s). This is a good solution for the regulation of the bus load.

The message generally just consists of the CAN-ID without the data. This type of transmission causes the lowest bus load in order to achieve the synchronisation of the process data.

Field name	**Content**	**Meaning**
COB-ID	080h	The COB-ID directly represents the used CAN-ID. The value can be changed via the object "*COB-ID SYNC*".
DLC	**0** / 1	Data length of the message in bytes **Standard application:** 0 → no transmission of useful data
BYTE 0	Counter	**Optional** The SYNC producer can send a *UNSIGNED8* counter [1, 240] which is used by the SYNC consumer to recognise the first valid SYNC when "SYNC start" is set. In most cases, the SYNC message is sent without the counter.

Example of a standard SYNC signal.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	Counter							
080h $_{Tx}$								

4.6.2.3. PDO Mapping

The PDO mapping is a complex process in which several areas of the OD work together. The following example shows how process data is "mapped" onto a TPDO. In this particular case, the example shows how the measurement signal "static inclination" from an inclination sensor by HYDAC Electronic GmbH is transmitted via the TPDO1.

The area "*PDO communication parameter*" defines when a PDO is supposed to be transmitted and the area "*PDO mapping parameter*" defines which objects from the OD will copy or read that particular PDO message.

> In order to change the mapping of a PDO, a process flow sequence has to be strictly adhered to; see chapter *4.6.2.5 Process flow sequence to change the "*PDO mapping".

For each event triggering the transmission of a PDO, the current content of the "mapped" objects will always be copied from the OD into the message (*TPDO*) or copied from the message into the objects (*RPDO*).

The CAN-ID transmitting the PDO object is defined by the parameter COB-ID from the area "communication parameter". It is calculated during runtime from the basis address and the device's Node-ID → in the example: Basis = 180h (TPDO1), Node-ID = 1 → 180h + 1 = 181h.

The number of objects used in the PDO is defined by the first entry of the "mapping parameter", object: "*Number of mapped objects in PDO"*.

Which particular objects will be connected with the PDO message is listed in the following sub entries of the "*xPDO mapping parameter*". Each of these entries represent a value which is transmitted in the PDO. The individual entries are references addressing one particular object via the index and the sub-index, see chapter *4.5.1.1 Addressing*.

The codification design of a process value parameter object reference is described in the object "*1st object to be mapped*" of the chapter *4.5.4.9 TPDO mapping parameter*. A good overview of the interaction between the several *OD segment* when setting up a *PDO CAN message* is shown in chapter *4.6.2.4 Overview diagram PDO* mapping.

The space requirements in the PDO correspond with the data length of the *Data type* in the object. The position of the subsequent object in the PDO is immediately after. It may for example happen that a following signal starts in the middle of a data byte if one the previous data bytes does not have a data length divisible by 8.

The length of a PDO CAN message is calculated from the sum of the individual data lengths of the process value parameter objects used. In the *Overview diagram below* these are 2 values with 16 bits each (2 bytes) and a value with 8 bits (1 byte). The result hereof is the length of the PDO:

(2 * 2 Bytes) + 1 Byte = 5 Bytes → DLC = 5.

A PDO is always limited to the length of a *CAN message*, which means 8 bytes (64 bits). If transmission of more than 8 Bytes is required, a further PDO has to be defined. The device manufacturer, however, defines the max. amount of PDOs in their software, see chapter *3.5.4.1 Number of the process data objects* supported by the device..

4.6.2.4. Overview diagram PDO mapping

The below diagram graphically explains the context between the structure of the PDO *CAN message* and the different *Segments of the OD*; see chapter *4.6.2.3 PDO Mapping*.

TPDO1 [signal static inlination]

CAN-ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
181h	5	1Eh	00h	51h	00h	00h			

OD: TPDO communication parameter

Index	Sub	Value	Name	Access	Datatype
...	...	...			
1800h	0	5	Highest sub-index	const	UNSIGNED8
1800h	1	180h+ Node-ID	COB-ID	rw	UNSIGNED32
1800h	2	FEh	Transmission type	rw	UNSIGNED8
1800h	3	00h	Inhibit time	rw	UNSIGNED16
1800h	5	0Ah	Event timer	rw	UNSIGNED16
...	...	...			

OD: TPDO mapping parameter

Index	Sub	Value	Name	Access	Datatype
...	...	...			
1A00h	0	3	Number of mapped objects	rw	UNSIGNED8
1A00h	1	60100010h	1st Object mapped	rw	UNSIGNED32
1A00h	2	60200010h	2nd Object mapped	rw	UNSIGNED32
1A00h	3	50000008h	3rd Object mapped	rw	UNSIGNED32
...	...	...			

OD: Signal parameter

Index	Sub	Value	Name	Access	Datatype
...	...	...			
5000h	0	00h	Safe value status	ro	UNSIGNED8
...	...	...			
6010h	0	1E00h	Slope long16	ro	INTEGER16
...	...	...			
6020h	0	5100h	Slope lateral16	ro	INTEGER16
...	...	...			

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4.6.2.5. Process flow sequence to change the "PDO mapping"

If the PDO mapping of a device is supposed to be changed, this can only be carried out following strict procedures. Should the procedure described below not be adhered to, the device will respond to the access sending the corresponding error message, see chapter *4.6.1.5 SDO abort transfer (abort)*.

Individual objects for the management of the "*PDO Mapping*" can be accessed via SDO commands, see chapter *4.6.1 SDO*.

- **Switching device to "Pre-Operational" mode**
    - *4.4.1 Overview of* network states.
    - *4.4.2 NMT*.
- **Declare the PDO as invalid**, for this purpose, bit 31 of the COB-ID has to be set to 1.
    - TPDO.*COB-ID* Bit 31 = set 1, e.g. 1800.1 = C00000180h
    - RPDO.*COB-ID* Bit 31 = set 1 e.g. 1400.1 = 800000200h180h
- **Deactivate the number of object references used in the PDO.** For this purpose, the number has to be set to 0.
    - see object: RPDO. "*Number of mapped objects in PDO*"
    - see object: RPDO. "*Number of mapped objects in PDO*"
- **Set new object references in the area "xPDO mapping parameter"**; → Memorise the number of new entries for the next step.
    - see chapter *4.6.2.3°PDO Mapping*
    - see chapter *4.5.4.7°RPDO mapping parameter*
    - see chapter *4.5.4.9°TPDO mapping parameter*
- **Set the number of object references used in the PDO to a new value.**
- **Set PDO back to valid.** For this purpose, bit 31 of the COB-ID is set to 0 or the object = 0 is set in order to activate the standard behaviour, i.e. TPDO1: $NODEID+180h.
    - TPDO.*COB-ID*
    - RPDO.*COB-ID*
- **Save changes permanently on the device**
    - see chapter *4.5.1.3°Objects serving as* functions
    - see object "*Save communication parameters*"
- **Switching device to "Operational" mode**
    - *4.4.1 Overview of* network states.
    - *4.4.2 NMT*.

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4.6.2.6. Configure example protocol TPDO1

In the following protocol, the TPDO1 of a device is configured as follows:

- COB-ID = 181h
- Transmission type = event-controlled (manufacturer-specific)
- Inhibit time = 0
- Event timer = 200 ms
- PDO Mapping with 3 object references
  - 6010.0 INTEGER16
  - 6020.0 INTEGER16
  - 5000.0 UNSIGNED8

```
CAN-ID (hex)
|      Direction: Tx (ECU → Device); Rx (Device → ECU)
|      |  Data Length
|      |  |  Data Bytes (hex)
|      |  |  |
+---  +- +  +- -- -- -- -- -- -- --
Heartbeat status = "Operational"
0701  Rx 1  05
0701  Rx 1  05
NMT command "enter pre-operational node-id=1"
0000  Tx 2  80 01
SDO write 4 byte command 1800.1 = C0000181h
→ deenable TPDO1 transmission
0601  Tx 8  23 00 18 01 81 01 00 C0
0581  Rx 8  60 00 18 01 00 00 00 00
SDO write 1 byte command 1800.2 = FEh (254d)
0601  Tx 8  2F 00 18 02 FE 00 00 00
0581  Rx 8  60 00 18 02 00 00 00 00
SDO write 2 byte command 1800.3 = 00h
0601  Tx 8  2B 00 18 03 00 00 00 00
0581  Rx 8  60 00 18 03 00 00 00 00
SDO write 2 byte command 1800.5 = C8h (200d)
0601  Tx 8  2B 00 18 05 C8 00 00 00
0581  Rx 8  60 00 18 05 00 00 00 00
SDO write 1 byte command 1A00.0 = 00h
→  deenable TPDO1 mapping
0601  Tx 8  2F 00 1A 00 00 00 00 00
0581  Rx 8  60 00 1A 00 00 00 00 00
SDO write 4 byte command 1A00.1 = 60100010h
0601  Tx 8  23 00 1A 01 10 00 10 60
0581  Rx 8  60 00 1A 01 00 00 00 00
```

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```
SDO write 4 byte command 1A00.2 = 60200010h
0601  Tx 8  23 00 1A 02 10 00 20 60
0581  Rx 8  60 00 1A 02 00 00 00 00
SDO write 4 byte command 1A00.3 = 50000008h
0601  Tx 8  23 00 1A 03 08 00 00 50
0581  Rx 8  60 00 1A 03 00 00 00 00
SDO write 1 byte command 1A00.0 = 03h
→ enable TPDO1 Mapping
0601  Tx 8  2F 00 1A 00 03 00 00 00
0581  Rx 8  60 00 1A 00 00 00 00 00
SDO write 4 byte command 1800.1 = 0h
→ enable TPDO1 transmission, standard COB-ID active
0601  Tx 8  23 00 18 01 00 00 00 00
0581  Rx 8  60 00 18 01 00 00 00 00
SDO write 4 byte command 1010.1 = 65766173h ("save")
→ Store parameters.Save all parameters
0601  Tx 8  23 10 10 01 73 61 76 65
0581  Rx 8  60 10 10 01 00 00 00 00
Heartbeat Status = "Pre-Operational"
0701  Rx 1  7F
NMT command "start node-id=<all>"
0000  Tx 2  01 00
TPDO1
0181  Rx 5  2A 01 55 00 00
TPDO1
0181  Rx 5  2A 01 55 00 00
Heartbeat Status = "Operational"
0701  Rx 1  05
```

4.6.3. SRDO

The devices described in this documentation (see chapter *1.1 Scope* of application) do **not** support any **functionally safe communication**.

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4.7. Layer setting services (LSS) Protocol

Via the LSS protocol, several specific LSS services in the device can be addressed. The main function of these services is to configure the most important communication parameters – *Baud rate* and *Node-ID* – without having specific knowledge of the *OD*. The LSS protocol is described in detail in the CiA 305.

Whether a device supports the LSS protocol can be recognised from the *EDS* parameter "*LSS_Supported"* and is described in chapter *3.8 LSS Protocol support.*

The following please find the most important information on this product summarised as an overview.

The access via LSS is supported for the following parameters:

- *Node-ID*
- *Baud rate*
- LSS address **-** corresponds with *Identity Object 1018h*

LSS address: This address controls the access to one particular device. It corresponds with the indications of the *OD.Identity Object*:

- Vendor ID *UNSIGNED32*
- Product Code *UNSIGNED32*
- Revision number and *UNSIGNED32*
- Serial number *UNSIGNED32*

The measurement system supports the following LSS services:

- **Switch mode services** enable switching mode*LSS-Status*
  - *Switch state selective* Address one particular device
  - *Switch state global* address all devices
- **Configuration services** change device configuration
  - *Configure Node-ID* configure Node-ID
  - *Configure bit timing parameters* Configure Baud rate
  - *Activate bit timing parameters* activate Baud rate
  - *Store configured parameters* save changes
- **Inquiry services** inquire device information
  - *Inquire LSS address* inquire LSS address
  - *Inquire Node-ID* inquire Node-ID

- **Identification services** identify device or devices
  - *LSS identify remote slave*
    Identification of devices within a certain array
  - *LSS identify slave*
    Response of all devices to the previous command
  - *LSS identify non-configured remote slave*
    Identification of non-configured devices, Node-ID = FFh
  - *LSS identify non-configured slave*
    Response of all devices to the previous command
- ***Fastscan*** Detect non-configured devices

4.7.1. LSS Communication model

Via the LSS protocol, an LSS master (control) can request particular services on a *LSS device* (device). The LSS protocol is mainly based on the *Master – Device* communication model. However, some LSS services classify the commands as *Request* and respond by using a *Response*.

With the LSS protocol, only **one single** device can be configured at a time. If there are several devices in the network at the same time, each one has to be separately switched to the configuration mode via its *LSS address*.

> To simplify the configuration of a device via the LSS protocol, it is helpful to connect only one device to the LSS master (control) at a time. In this case, the command "*switch mode global*" for *status switch* can be used.

4.7.1.1. LSS status diagram

In order to process the communication in the device (*LSS consumer*), it can take on two different operational modes.

LSS Waiting: after device start-up, see also chapter *4.4 Network Management*, the device automatically takes on this mode. In this state, the device accepts the *LSS "switch mode services"* commands as well as *LSS "identification services"*.

LSS Configuration: the device takes on this mode after having received a *"Switch Mode" command*. **Only one device at a time** may take on this device mode. Parameters can only be read and written and changes can only be stored permanently if the operating mode "LSS Configuration" is active. For this purpose, the *LSS "configuration"* and the *LSS "inquire"* commands are available.

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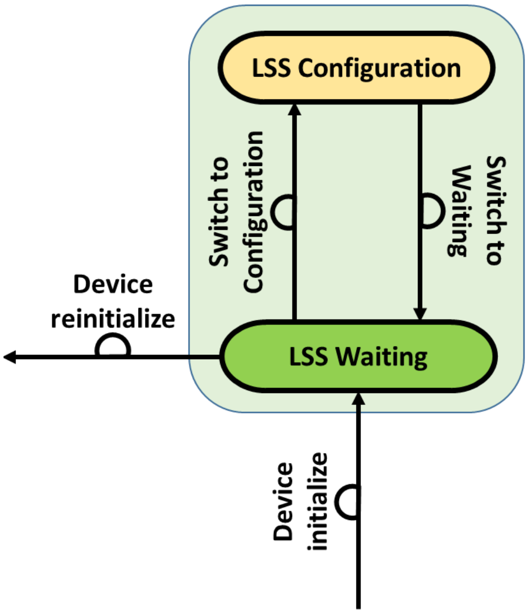

4.7.1.2. LSS command structure

The structure of the *CAN command message* is similar to a *SDO protocol-message:* Two COB-IDs are used for sending and receiving here as well. Another similarity is that the first byte of the message is used as a command code. The COB-ID of the LSS command, however, is strictly defined and does not depend on the Node-ID of the device.

Field name	**Content**	**Meaning**
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device) [Tx: ECU → Device]
COB-ID	7E4h Rx	COB-ID of the LSS response (device → controller) [Rx: Device → ECU]
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code serves to distinguish the different LSS services and their responses.
BYTE 1 - 7	Data	Useful data Data length and content depend on the related LSS service command.

4.7.2. LSS Switch commands

This command is used to switch the active *LSS condition* of a device. The device can only be parameterised with other commands if the "*LSS configuration*" mode is active. This state may not be taken on by more than one device within the network at a time.

4.7.2.1. LSS Switch state global

If only one single device is connected to the master (control), its *LSS condition* can be switched directly without the knowledge of its *LSS address*. The command is not responded to by the device.

> If more than one device is connected to the control, all devices will switch to another mode when receiving this command. This means that in the case the "*LSS configuration*" mode should be active, this might lead to undefined behaviour.

Field name	**Content**	**Meaning**
COB-ID	7E5h$_{Tx}$	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* **04h** Switch state global service
BYTE 1	Mode	To be enabled *LSS condition* *UNSIGNED8* 00h enable status "*LSS Waiting*" 01h enable status "*LSS configuration*"
BYTE 2 - 7	Reserved	

The example shows how a device is switched to the "*LSS configuration*" mode.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Mode	Reserved					
7E5h$_{Tx}$	**04h**	01h						

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4.7.2.2. LSS switch state selective

If several devices are connected to the CAN network, each device has to be addressed and parameterised separately. For this purpose, the master (control) has to send 4 consecutive messages in total. Each message contains a parameter of the *LSS address*.

Field name	**Content**	**Meaning**	
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)	
DLC	8	Data length of the message in bytes	
BYTE 0	Command	Command code **40h – 43h** **43h** Please follow the commands list below.	*UNSIGNED8* **Request** **Response**
BYTE 1 – 4	Data	*LSS address* individual parameters The data to be transmitted depends on the command, see below list of commands.	*UNSIGNED32*
BYTE 5 – 7	Reserved		

Context between the command code and the LSS address data transmission. The individual request commands should be sent to the device in ascending order.

Command	**Direction**	**Data**	**Description**
40h	Request	*UNSIGNED32*	send vendor ID
41h	Request	*UNSIGNED32*	send product code
42h	Request	*UNSIGNED32*	send revision number
43h	Request	*UNSIGNED32*	send serial number
44h	Response	Reserved	No response data

Please see below how a device is switched to "*LSS configuration*" mode using a defined *LSS address*. For this purpose, 4 *Command requests* carrying the particular LSS address data will be sent to the device in consecutive order. After the command sequence has expired, the device responds by means of a *Response command.*

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The LSS address used in the example:

Vendor-ID	DAh
Product Code	E2155h
Revision Number	80000h
Serial Number	12345678h

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Data				Reserved		
7E5h Tx	**40h**	DAh	00h	00h	00h			
7E5h Tx	**41h**	55h	21h	0Eh	00h			
7E5h Tx	**42h**	00h	00h	08h	00h			
7E5h Tx	**43h**	78h	56h	34h	12h			
7E4h Tx	**44h**							

4.7.3. LSS configuration commands

Via the "LSS Configurations" command, the parameters of a device can be read and changed. These commands, however, can only be used if the device is in the *LSS condition* "*LSS configuration*".

4.7.3.1. Configure Node-ID

The *Node-ID* of a device can be changed using this command. The command is implemented according to *Request response model*.

Please observe: Only one device may be in the "*LSS configuration*" state at a time.

To save the new Node-ID the "*Store configuration*" command has to be carried out afterwards.

In order to activate the new Node-ID, the *NMT command „Reset communication*“ or "*Reset Node*" has to be inquired. Without a device "reset", the current Node-ID remains active..

The commands "request" and "response" have different structures. The structures of both messages are shown below.

Request

Field name	**Content**	**Meaning**
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes

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Field name	Content	Meaning
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **11h "Configure Node-ID"**
BYTE 1	Node ID	Required Node-ID *UNSIGNED8* Value range: 1 – 127 and 255 ("non-configured")
BYTE 2 – 7	Reserved	

Response

Field name	Content	Meaning
COB-ID	7E4h Rx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **11h "Configure Node-ID"**
BYTE 1	Error Code	Error number *UNSIGNED8* **0 Node-ID successfully applied** **1 invalid Node-ID value** 255 device-specific error → "Specific Error"
BYTE 2	Specific Error	Device-specific error number *UNSIGNED8* 0 Error Code ≠ 255
BYTE 3 – 7	Reserved	

The following section shows how to set the Node-ID 0Ah (10d) successfully in the device by means of the LSS command "Configure Node-ID".

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Data		Reserved				
7E5h Tx	**11h**	0Ah						
7E4h Rx	**11h**	00h	00h					

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4.7.3.2. Configure bit timing

The *Baud rate* of a device can be changed using this command. The command is implemented according to *Request response model*.

Please observe: Only one device may be in the "*LSS configuration*" state at a time.

To save the new Baud rate ID the "*Store configuration*" command has to be carried out afterwards.

To activate the new Baud rate, the *NMT command* "*Reset communication*" or "*Reset Node*" can be inquired afterwards, or the LSS command "*Activate bit timing parameters*" is used.

The commands "request" and "response" have different structures. The structures of both messages are shown below.

Request

Field name	**Content**	**Meaning**
COB-ID	7E5h Tx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **13h** **"**Configure bit timing"
BYTE 1	Table selector	Active Baud rate table *UNSIGNED8* 0 Standard CiA Baud rate table
BYTE 2	Table index	Baud rate table index *UNSIGNED8* Active Baud rate see Object "*Baud* rate*"* 0 1000 kbit/s 1 800 kbit/s 2 500 kbit/s 3 250 kbit/s 4 125 kbit/s 5 reserved 6 50 kbit/s 7 20 kbit/s 8 10 kbit/s
BYTE 3 – 7	Reserved	

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Response

Field name	Content	Meaning
COB-ID	7E4h Rx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **13h** **"**Configure bit timing"
BYTE 1	Error Code	Error number *UNSIGNED8* **0 Node-ID successfully applied** **1 Baud rate index not supported** 255 device-specific error → "Specific Error"
BYTE 2	Specific Error	Device-specific error number *UNSIGNED8* 0 Error Code ≠ 255
BYTE 3 – 7	Reserved	

The following section shows how to set the Baud rate 500 kbit/s, Index = 2 successfully in the device by means of the LSS command "Configure bit timing".

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Data		Reserved				
7E5h Tx	**13h**	00h	02h					
7E4h Rx	**13h**	00h	00h					

4.7.3.3. Activate bit timing parameters

A slightly complex procedure is required to activate a new Baud rate after having changed and stored it. The command "activate bit timing" must be processed almost exactly at the same time by all the network participants in order to switch all participants to the new Baud rate and avoid communication errors.

The command is not responded to by the device.

Switchover procedure:

- The command transmits a delay.
- All the participants have to wait two times for this delay to expire before they can send their information using the new Baud rate.

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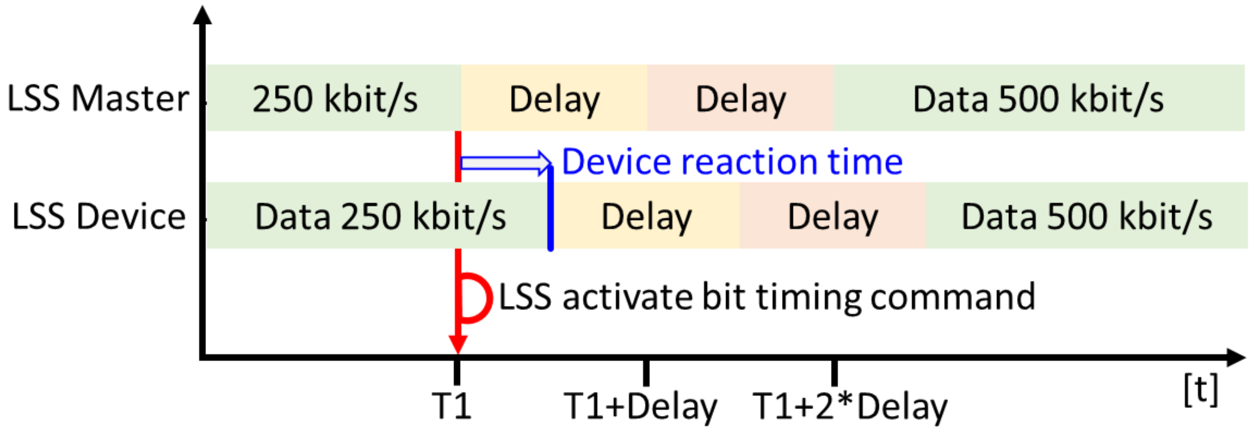
- The first half of the delay is for de-initialisation of all participants. Within this time range, all the participants should terminate the sending of their messages; "device reaction time".
- The delay should be chosen in such a way that even the network participant with the longest reaction time has stopped sending messages within the first phase.
- The first phase serves as reinitialisation. After the second phase has expired, messages may be sent with the new Baud rate.



Process diagram "activate bit timing"

Field name	**Content**	**Meaning**
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* **15h** Switch state global service
BYTE 1	Delay	Waiting period *UNSIGNED16* Delay for switchover in [ms]; see *Switchover diagram*
BYTE 2 – 7	Reserved	

The example instructs all participants in "*LSS configuration*" to activate the newly configured Baud rate.

The LSS master specifies a delay of 2 s → 2000d [ms] → 07D0h

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Delay		Reserved				
7E5h Tx	**15h**	D0h	07h					

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4.7.3.4. Store configuration

This command enables changes to the *Node-ID* and the *Baud rate* to be stored permanently on the device. The command is implemented according to *Request response model*.

Please observe: Only one device may be in the "*LSS configuration*" state at a time.

The commands "request" and "response" have different structures. The structures of both messages are shown below.

Request

Field name	Content	Meaning
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **17h** **"**Store configuration"
BYTE 1 – 7	Reserved	

Response

Field name	Content	Meaning
COB-ID	7E4h Rx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **17h** **"**Store configuration"
BYTE 1	Error Code	Error number *UNSIGNED8* **0** **storage carried out successfully** 1 command is not supported **2** **storage access denied** 255 device-specific error → "Specific Error"
BYTE 2	Specific Error	Device-specific error number *UNSIGNED8* 0 Error Code ≠ 255

E

Field name	Content	Meaning
BYTE 3 – 7	Reserved	

The following section shows how to store recent changes in the device permanently with the LSS command "store configuration".

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Data		Reserved				
7E5h Tx	**17h**							
7E4h Rx	**17h**	00h	00h					

4.7.4. LSS Inquire command

With the help of the "LSS inquire command", the individual sections of the *LSS address* as well as the recent Node-ID of all devices which are currently in the "*LSS configuration*" mode can be inquired.

If several devices are active at the same time, all of them will respond almost synchronously. The order of the responses cannot be predefined, however. For this reason, only one device at a time should be in the "*LSS configuration*" mode.

4.7.4.1. Inquire Identity Vendor-ID

The CiA manufacturer code as is defined in the "*OD.Identity Object* .Vendor-ID (1018.1)" via this command. The command is implemented according to *Request response model*.

Please observe: Only one device may be in the "*LSS configuration*" state at a time.

The commands "request" and "response" have different structures. The structures of both messages are shown below.

Request

Field name	**Content**	**Meaning**
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **5Ah** **"**Inquire Vendor-ID"
BYTE 1 – 7	Reserved	

E

Response

Field name	Content	Meaning
COB-ID	7E4h Rx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **5Ah** **"**Inquire Vendor-ID"
BYTE 1 – 4	Vendor ID	Manufacturer's code *UNSIGNED32* CiA manufacturer's code corresponds with the object "*OD.Identity Object*.Vendor ID"
BYTE 5 – 7	Reserved	

The following example shows how the CiA manufacturer code (HYDAC Electronic GmbH: DAh) of the device is inquired.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Data				Reserved		
7E5h Tx	**5Ah**							
7E4h Rx	**5Ah**	DAh	00h	00h	00h			

4.7.4.2. Inquire Identity Product-Code

Via this command, the manufacturer-specific product code, as it is defined in the "*OD.Identity Object*.Product code (1018.2)", can be inquired. The command is implemented according to *Request response model*.

Please observe: Only one device may be in the "*LSS configuration*" state at a time.

The commands "request" and "response" have different structures. The structures of both messages are shown below.

E

Request

Field name	Content	Meaning
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **5Bh** **"**Inquire Product-Code
BYTE 1 – 7	Reserved	

Response

Field name	Content	Meaning
COB-ID	7E4h Rx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **5Bh** **"**Inquire Product-Code
BYTE 1 – 4	Product code	Product code *UNSIGNED32* Manufacturer-specific product code corresponds with the object "*OD.Identity Object*.Product code".
BYTE 5 – 7	Reserved	

The following example shows how to request the manufacturer-specific product code (Example: E2155h) of the device.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Data				Reserved		
7E5h Tx	**5Bh**							
7E4h Rx	**5Bh**	55h	21h	0Eh	00h			

E

4.7.4.3. Inquire Identity Revision-Number

This command serves to inquire the product revision number as it is defined in the "*OD.Identity Object*.Revision number (1018.3)". The command is implemented according to *Request response model*.

Please observe: Only one device may be in the "*LSS configuration*" state at a time.

The commands "request" and "response" have different structures. The structures of both messages are shown below.

Request

Field name	**Content**	**Meaning**
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **5Ch "**Inquire Revision-Number"
BYTE 1 – 7	Reserved	

Response

Field name	**Content**	**Meaning**
COB-ID	7E4h Rx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **5Ch "**Inquire Revision-Number"
BYTE 1 – 4	Revision-Number	Revision number *UNSIGNED32* Product revision number corresponds with the object "*OD.Identity Object*.Revision number"
BYTE 5 – 7	Reserved	

E

The following example shows how to request the product revision number (Example: 80000h) of the device.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Data				Reserved		
7E5h Tx	**5Ch**							
7E4h Rx	**5Ch**	00h	00h	08h	00h			

4.7.4.4. Inquire Identity Serial-Number

This command serves to inquire the device serial number as it is defined in the "*OD.Identity Object*.Serial number (1018.4)". The command is implemented according to *Request response model*.

Please observe: Only one device may be in the "*LSS configuration*" state at a time.

The commands "request" and "response" have different structures. The structures of both messages are shown below.

Request

Field name	**Content**	**Meaning**
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **5Dh** **"**Inquire Serial-Number"
BYTE 1 – 7	Reserved	

Response

Field name	**Content**	**Meaning**
COB-ID	7E4h Rx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **5Dh** **"**Inquire Serial-Number"

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Field name	Content	Meaning
BYTE 1 – 4	Serial number	Serial Number *UNSIGNED32* Device serial number corresponds with the object "*OD.Identity Object*.Serial number"
BYTE 5 – 7	Reserved	

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The following example shows how to request the device serial number (Example: 1EDDh).

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Data				Reserved		
7E5h Tx	**5Dh**							
7E4h Rx	**5Dh**	DDh	1Eh	00h	00h			

4.7.4.5. Inquire Node-ID

This command serves to inquire the currently active Node-ID as it is defined in the "*OD.Node-ID.Active node-ID* (2001.1)". The command is implemented according to *Request response model*.

Please observe: Only one device may be in the "*LSS configuration*" state at a time.

The commands "request" and "response" have different structures. The structures of both messages are shown below.

Request

Field name	**Content**	**Meaning**
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **5Eh** **"**Inquire Node-ID"
BYTE 1 – 7	Reserved	

Response

Field name	**Content**	**Meaning**
COB-ID	7E4h Rx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* The command code is identical for request and for **response**. **5Eh** **"**Inquire Node-ID"

E

Field name	Content	Meaning
BYTE 1	Node ID	Active Node-ID *UNSIGNED32* Currently active Node-ID of the device see object "*OD.Node-ID.Active node-ID*"
BYTE 2 – 7	Reserved	

The following example shows how to request the device's currently active Node-ID (example: 01h).

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Data	Reserved					
7E5h Tx	**5Eh**							
7E4h Rx	**5Eh**	01h						

4.7.5. LSS Identify commands

The LSS identity commands serve to find out how many devices with LSS protocol support are currently connected to the CAN network.

4.7.5.1. Identify remote slave

If more devices are connected to the CAN network, the number of devices with LSS protocol support can be determined. For this purpose, the master (control) has to send 6 consecutive messages in total. The messages contain parameters of the *LSS address*. In order to set a limit to the selection of the devices, the manufacturer and product code are firmly defined. The selection is limited using a pre-defined value range for the revision and serial number.

If devices exist which correspond with the LSS address section which is pre-defined by the command sequence, these can respond with the "*Identify slave*" command.

Field name	Content	Meaning
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* **46h – 4Bh** **Request** Please follow the commands list below.
BYTE 1 – 4	Data	*LSS address* individual parameters *UNSIGNED32* The data to be transmitted depends on the command, see below list of commands.

Field name	Content	Meaning
BYTE 5 – 7	Reserved	

Relationship between the command code and the LSS address section transmission. The individual request commands should be sent to the device in ascending order.

Command	Direction	Data	Description
46h	Request	*UNSIGNED32*	Define vendor ID
47h	Request	*UNSIGNED32*	Define product code
48h	Request	*UNSIGNED32*	Define revision number minimum
49h	Request	*UNSIGNED32*	Define revision number maximum
4Ah	Request	*UNSIGNED32*	Define serial number minimum
4Bh	Request	*UNSIGNED32*	Define serial number maximum

Please see below how a device is switched to "*LSS configuration*" mode using a defined *LSS address*. For this purpose, 4 *Command requests* carrying the particular LSS address data will be sent to the device in consecutive order. After the command sequence has expired, a device responds with the "*Identify slave"* command.

The LSS address used in the example:

Vendor-ID	DAh	
Product Code	E2155h	
Revision Number	80000h	Range: 40000h – 80000h
Serial Number	12345678h	Range: 1000h – 50000000h

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Data				Reserved		
7E5h Tx	**46h**	DAh	00h	00h	00h			
7E5h Tx	**47h**	55h	21h	0Eh	00h			
7E5h Tx	**48h**	00h	00h	04h	00h			
7E5h Tx	**49h**	00h	00h	08h	00h			
7E5h Tx	**4Ah**	00h	10h	00h	00h			
7E5h Tx	**4Bh**	00h	00h	00h	50h			
7E4h Rx	**4Fh**							

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4.7.5.2. Identify slave

Possible response to the previous command by the device, see chapter *4.7.5.1 Identify remote slave*.

Field name	Content	Meaning
COB-ID	7E4h Rx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* **4Fh** **"**LSS identify slave protocol"
BYTE 1 – 7	Reserved	

4.7.5.3. Identify non-configured remote slave

Command for the recognition of non-configured devices with LSS protocol support within the network. Devices which are classified as "non-configured" are the ones whose "pending Node-ID" (see *OD.Node-ID*) is invalid, e.g. = FFh.

Non-configured devices can respond using the command "*Identify non-configured slave*".

Field name	Content	Meaning
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* **4Ch** **"**LSS identify non-configured remote slave"
BYTE 1 – 7	Reserved	

Example of a response of a non-configured device to the LSS master request for identification.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	Reserved						
7E5h Tx	**4Ch**							
7E4h Rx	**50h**							

E

4.7.5.4. Identify non-configured slave

Possible response of a non-configured device to a LSS master request "Identify non-configured remote slave", see chapter *4.7.5.3 Identify non-configured remote slave*.

Field name	Content	Meaning
COB-ID	7E4h Rx	COB-ID of the LSS command (device → controller)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* **50h** "LSS identify non-configured slave"
BYTE 1 – 7	Reserved	

4.7.6. LSS Fastscan

With the fastscan protocol, a LSS master CAN-IDentify the *LSS address* of unknown and non-configured devices. At the beginning of such a request, all non-configured devices have to be in the "*LSS Waiting*" mode.

The inquiry will be initiated by the LSS master with a particular request ("Bit Check" = 128) in order to mark the start of the request sequence. This inquiry should be confirmed by all LSS devices which have not yet been configured with the response "*Identify slave*". With this response, the LSS master recognises that further LSS devices need to be configured.

That is to say, the fastscan protocol performs a search for existing LSS addresses. For this purpose, all sections of the *LSS address* are inquired bit by bit and sequentially. LSS devices with matching address sections confirm the related request positively by sending the response "*Identify slave"*. If the recently inquired address section does not match, no response will be sent by the LSS device. In this case, the LSS master waits for a defined time, corrects the address section it has already received and requests the next address section. Therefore, up to 132 ($4 * 32_{bit} + 4$) single requests are required in order to detect the LSS address of a particular LSS device.

If an LSS device has been clearly identified, it will automatically switch to the "*LSS configuration*" state after the sequence has expired and confirm that the process has been successful by "*Identify slave"*. The LSS device can now be configured by the LSS master accordingly using the LSS functions described above.

Please see the CiA 305 for a more detailed description.

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Field name	Content	Meaning
COB-ID	7E5h Tx	COB-ID of the LSS command (controller→device)
DLC	8	Data length of the message in bytes
BYTE 0	Command	Command code *UNSIGNED8* **51h** **"**LSS Fastscan"
BYTE 1 – 4	IDNumber	Inquiry *UNSIGNED32* Currently inquired address sequence of the *LSS address.*
BYTE 5	Bit Check	Bit position *UNSIGNED8* Current bit positions to be checked within the currently active LSS address section of the inquiry. The LSS device checks all the superordinate bits, including this bit position, for equality of the transmitted IDnumber compared with the LSS address sequence currently to be checked. Example: Bit Check = 28d Check Bit 31, 30, 29, 28 **Special case** Bit Check = 128d (80h); IDNu, Sub, Next = 0 → Start Fastscan
BYTE 6	LSS Sub	LSS-Adress Index *UNSIGNED8* Current section of the *LSS address* to be checked. **0** Vendor ID **1** Product code **2** Revision number **3** Serial number
BYTE 7	LSS Next	Next LSS-Adress Index *UNSIGNED8* Value range, see LSS Sub.

Example: Start LSS fastscan with a non-configured LSS device

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
CANID	CMD	IDNumber				BitChk	Sub	Next
7E5h Tx	**51h**	0000000h				80h	0h	0h
7E4h Rx	**4Fh**							

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4.7.7. Example: setting the Node-ID and Baud rate via LSS

The following example shows how a LSS master switches one particular device to the "*LSS configuration*" state via the "*global switch*" command. Subsequently, a new *Node-ID* (2) and *Baud rate* (250 kbit/s) will be defined. These will be stored permanently on the device and finally, the device will be restarted with the new settings.

```
CAN-ID (hex)
|      Direction: Tx (ECU → Device); Rx (Device → ECU)
|      |  Data Length
|      |  |  Data Bytes (hex)
|      |  |  |
+---   +- +  +- -- -- -- -- -- -- --
LSS-Master "Switch mode global" according to "LSS configuration"
07E5  Tx 8  04 01 00 00 00 00 00 00
LSS-Master "Configure Node-ID"; Node-ID = 2
07E5  Tx 8  11 02 00 00 00 00 00 00
LSS-Device positive Response
07E4  Rx 8  11 00 00 00 00 00 00 00
LSS-Master "Configure bit timing"; Baud rate Index=3 (250 kbit/s)
07E5  Tx 8  13 00 03 00 00 00 00 00
LSS-Device positive Response
07E4  Rx 8  13 00 00 00 00 00 00 00
LSS-Master "Store configuration"
07E5  Tx 8  17 00 00 00 00 00 00 00
LSS-Device positive Response
07E4  Rx 8  17 00 00 00 00 00 00 00
LSS-Master "Switch mode global" according to "LSS Waiting"
07E5  Tx 8  04 00 00 00 00 00 00 00
NMT-Master "Reset all Node"
0000  Tx 2  81 00
Boot-up Node-ID = 2
0702  Rx 1  00
TPDO1 messages from Node-ID = 2
0182  Rx 5  A9 04 FE FD 01
0182  Rx 5  A9 04 FE FD 01
```

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5. Software tools

In the following, please find a description of all the tools which are helpful when using CAN based device communication.

5.1. HMG 4000

The HMG 4000 portable data recorder is a mobile measurement and data gathering device for measuring tasks for hydraulic and pneumatic systems and machines in industrial sectors as well as mobile sectors.

The HMG 4000 can record the signals of up to 38 sensors at once. For this purpose, HYDAC ELECTRONIC offers special sensors that are automatically detected by the HMG 4000 with configurable settings for the measured variable, measuring range and unit. In addition to this, the HMG 4000 is also able to process sensors with the standard analogue output signals, such as 0 .. 10 VDC or 4 .. 20 mA.

A very useful feature of the measurement device is the processing of CAN signals. The HMG 4000 is able to visualise and record process data of devices in the form of process values. This can be very useful, especially when signals from analogue sensors need to be recorded with CAN information simultaneously. This means it is possible to put information about the transmission performance of a combustion engine in relation to the pressure values in the hydraulic unit of a work function in a machine.

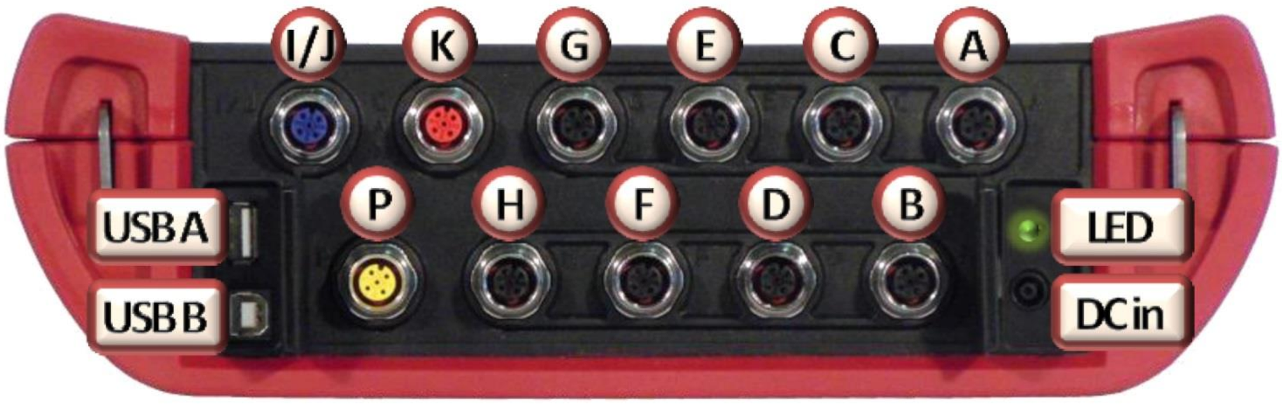
However, the HMG 4000 not only offers the possibility to record process values. It also has the ability to configure devices with a CAN communication interface. The "CAN Tools" function of the HMG 4000 is able to modify the "*Object dictionary*" via *EDS files* and configure the *Node-ID* and the *Baud rate* via the *LSS Protocol*. In addition to this, it is able to evaluate and report incoming messages via the CAN connection. This makes the HMG 4000 a robust and handy measurement device with "outdoor" quality, providing nearly all the features of standard CAN analysers and configurators.

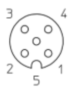
In the following a few important notes are listed for the handling of CAN devices in conjunction with the HMG 4000. Further information can be found in the device's operating manual.

https://www.hydac.com Section: Download / Electronic

5.1.1. HMG 4000 pin assignment

The HMG 4000 has 11 * M12 5 pin connections as socket connectors. All connections provide a power supply of 12 VDC / 200 mA (total current max. 500 mA). The CAN connection is the socket marked with "**K**" and is made of red plastic. The assignment of the CAN connection corresponds with the requirements of the CiA 303-1, see chapter *4.2.4 Standard pin* connections.



Socket		Colour	Channel	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5
A … G		black	A … G	+UB	n.c.	Signal	GND	HSI
H		black	H	+UB	n.c.	Signal	GND	HSI
				n.c.	PT 100 Force +	PT 100 Sense +	PT 100 GND	n.c.
I/J		blue	I/J	+UB	Digital-IN I	Digital-IN J	GND	n.c.
CAN/HCSI		red	K	n.c.	+UB	GND	CANH	CANL
P		yellow	IO-Link	+UB	Q2	GND	Q1/C	n.c.
			Prog	+UB	n.c.	GND	Q/C	n.c.

5.1.2. PDO Process values used as measured values

The HMG 4000's "measured values" feature enables data ranges from a PDO to be visualised as a measured value. For this purpose, the channels "CAN-Bus/HCSI (K)" are available in the settings for the measured values.

In below example, the process data "signal static inclination" and "signal acceleration" are shown from an inclination sensor by HYDAC Electronic GmbH. The settings required for the measurement of the "signal static inclination (K1 slope long)" is explained more in detail.

 This symbol enables access to the measured values of channel settings.

 Tapping this symbol expands the function bar at the left of the screen, where short explanatory notes describe the function of each symbol.

 This symbol opens a sub-function and in this particular case, opens up the channel range "CAN-Bus/HCSI (K)". After opening, a list of max. 28 single channels becomes available.

Each single channel represents exactly one *Signal or process value*, which generally corresponds with only one section of a *PDO message*. Each channel can be activated separately and configured individually.

The settings of the CAN interface are common for all channels. The HMG 4000 function "measured values" has its own CAN setting parameters which are independent of other areas in the HMG 4000.

The mode "**evaluate messages"** has to be active in order to enable the evaluation of signals from CAN messages.

The ***Baud rate*** has to correspond with the device which is being evaluated.

The "***Internal terminating resistor***" should always be activated when the HMG 4000 is not connected to an existing CAN network – for instance, when a particular device is directly connected to the measurement device. The internal terminating resistor should, however, be deactivated, when the measurement device is connected to an existing, correctly terminated network.

Under the same circumstances, it is also necessary to have the function "**active silent monitoring, confirm messages**" activated. The "passive monitoring" should be used when the HMG 4000 is connected to an existing CAN network and is supposed to monitor and display messages emerging here.

After opening an individual channel, its settings can be changed as well as viewed.

Channel characteristics	Description
Message type	The option "CANopen-PDO" is available for the evaluation of *Process data*. For other tasks, there are message type options available for J1939 as well as for proprietary *CAN messages*.
Name	The channel name can be assigned individually.

Channel charac-teristics	Description
measuring range	This feature serves to describe the value range and, therefore, the scaling of the process value to be displayed. In a sub-menu point, the number of decimal places, the max. and min. value of the measuring range and the physical unit can be entered. The information on the measuring range can be found in the menu process data in the product description. see chapter: *3.3 Process* data *4.5.4.9 TPDO mapping parameter*
Resolution	The resolution defines the value of a single bit of the digital val-ue transmitted with the PDO which includes the "increment" (resolution) of the scaled process value. (Digital value * resolution) - Offset = Process value Example: 0.01 °/bit 0001h = 0.01°; 0005h = 0.05°; 04B0h = 12.00° The information on the resolution and the offset can be found in the menu process data in the product description. see chapter: *3.3 Process* data *4.5.4.9 TPDO mapping parameter*
Offset	Zero offset of the process value, see resolution.
COB-ID	CAN-ID of the PDO message as *Hexadecimal value*. This value has to correspond with the CAN-ID of the PDO which is going to be interpreted. As each measurement channel of the HMG 4000 is independent, the CAN-ID has to be predetermined the same way as the message will be transmitted. An automatic calculation via the *Node-ID* is not possible. see chapter: *4.5.4.6 RPDO communication parameter* *4.5.4.8 TPDO communication parameter* Example: *TPDO1.COB-ID 1800.1* $NODEID+40000180h *Active Node-ID* 5 Measured value **COB-ID 185h**

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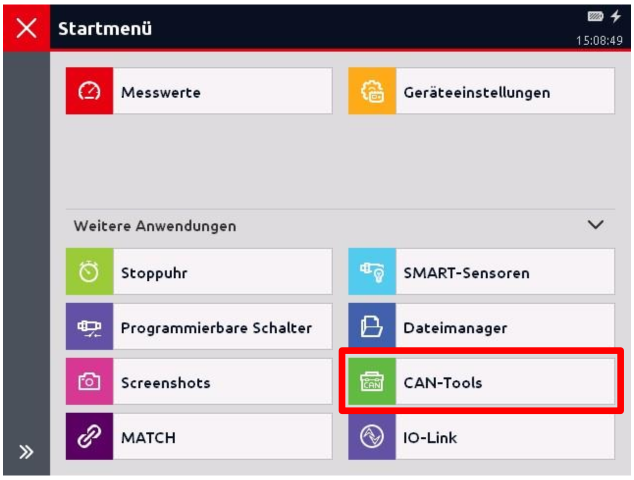
Channel characteristics	Description
Representation of numeric figures	The digital value of the process value transmitted with the PDO. The data length of the digital value is defined via the channel setting "bit length". Unsigned integer *UNSIGNED* Signed integer *INTEGER* Floating point number *REAL* The information on the data type can be found in the menu process data in the product description. see chapter: *3.3 Process* data *4.5.4.9 TPDO mapping parameter*
Bit position	The bit position defines the position of the digital value's first bit within the data range of *CAN message*. The bit position of a process value is defined via the PDO mapping. The counting method for the bit position starts with 0, which means the first bit within the CAN message's data range has the bit positon 0. see chapter: *4.6.2.3 PDO Mapping* *4.6.2.4 Overview diagram PDO* mapping
Bit length	The bit length defines the number of data bits occupied by the digital value within the data range of *CAN message*. The information on the data type can be found in the menu process data in the product description. see chapter: *3.3 Process* data *4.5.4.9 TPDO mapping parameter*

5.1.3. Functions of the HMG 4000 "CAN tools"

The HMG 4000 offers suitable features for many of the characteristics described in this protocol description.

The most important features are briefly explained in the following chapters.



5.1.3.1. Wizard

The "wizard" offers the ability to change the most important CANopen settings, such as *Baud rate* and *Node-ID*, without detailed knowledge of the device. The wizard uses *LSS Protocol* for that purpose. Using this universal protocol, all devices supporting LSS can be recognised and configured.

As described in chapter *4.7.1 LSS Communication* model, only one device at a time should be connected to the HMG 4000 while this function is used. Via the button "next", the search for a LSS capable device is started and its *LSS address* is read. The *Baud rate* and *Node-ID* can subsequently be changed.

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5.1.3.2. Electronic Data Sheet (EDS)

Via the function "Electronic Data Sheet (EDS)", objects of the device "*Object dictionary (OD)*" can be changed as well as imported.

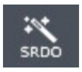
While using this function, several devices may be connected at the same time. This is why it is inevitable to preselect the *Node-ID* (Node-ID) of the device you wish to use before importing any data.

The suitable file for the device used can now be selected from a list of EDS files available on the HMG 4000. The files often contain the manufacturer's part number as an identifier in the file name. In a first step, available files have to be copied into the "file manager" in the HMG 4000 directory "CanTools\Eds\General". After "open", all the objects will be loaded from the OD and visualised as a list.

Object entries can now be changed as well as viewed. In order to store them on the device permanently, the function "memory" must be used. This function performs the *Object function* "*Save all parameters".*

Note: If the Node-ID or the Baud rate are changed directly in the EDS window, the function "*Save LSS parameters*" also has to be changed via the EDS window, as described in chapter *4.5.4.3 Storage and restoring (general communication objects).*

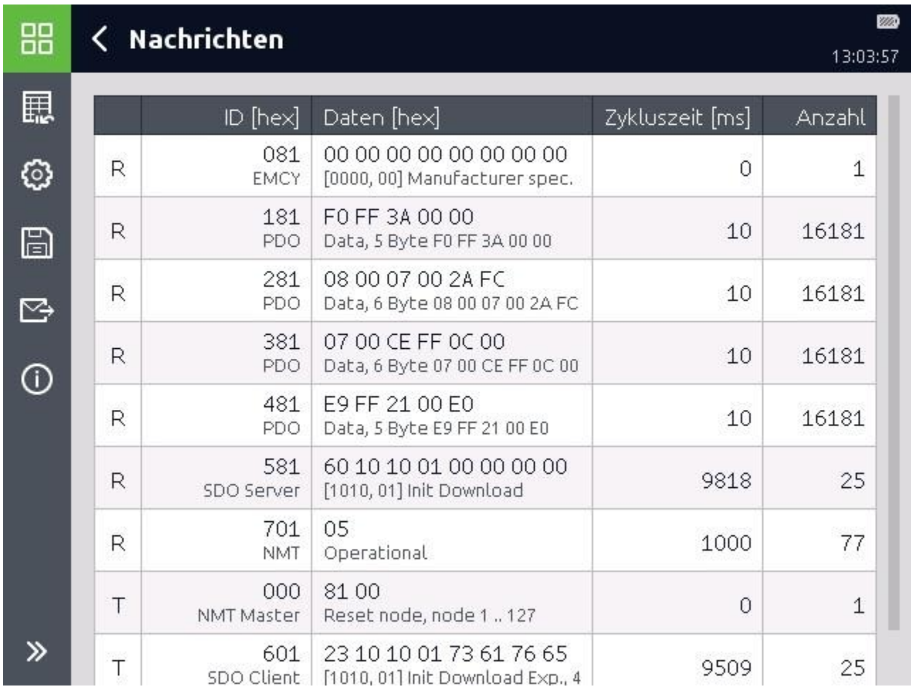
The PDO wizard is a special feature. With this function, the *PDO Mapping* can be configured very easily. The PDO wizard leads you through all the objects of the "*communication*" and "*mapping parameter*" step by step.



The SRDO wizard is another special feature. This special wizard helps you carry out the more complicated configurations of safety-relevant process values. Whether such values are supported by the device used is described in chapter *3.4 Functionally safe process* data.

5.1.3.3. Messages

The function "messages" offers the opportunity to list *CAN messages* which are connected to the CAN chronologically or grouped according to *CAN-ID*. The received messages can be interpreted and represented via the HMG 4000 by order of importance, see chapter *4.3.2 Meaning of the* CAN-ID. Data flow direction R (=Rx) received by the HMG; T (=Tx) sent by the HMG.

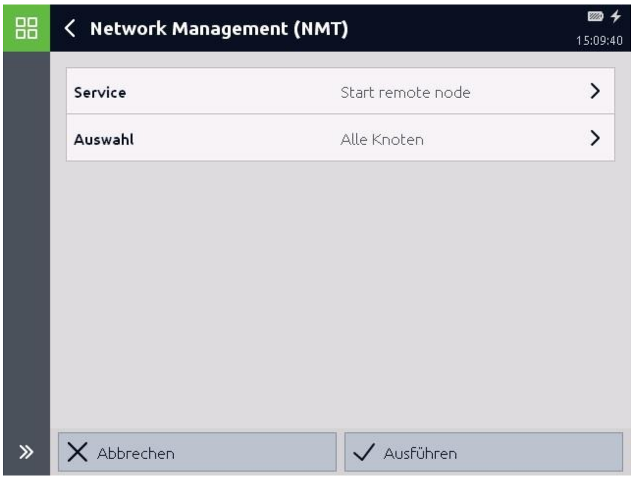


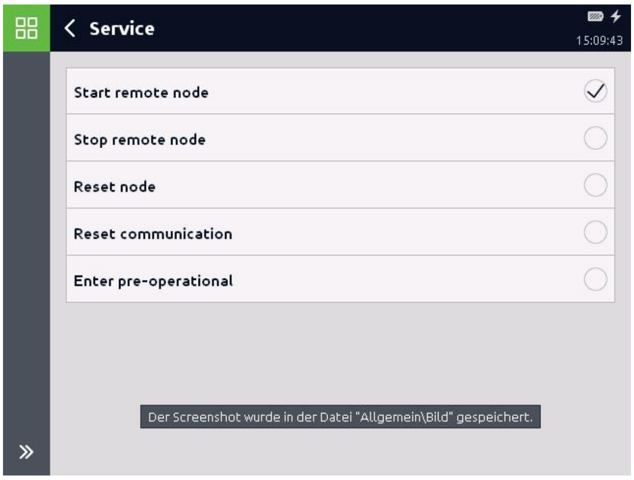
	ID [hex]	Daten [hex]	Zykluszeit [ms]	Anzahl
R	081 EMCY	00 00 00 00 00 00 00 00 [0000, 00] Manufacturer spec.	0	1
R	181 PDO	F0 FF 3A 00 00 Data, 5 Byte F0 FF 3A 00 00	10	16181
R	281 PDO	08 00 07 00 2A FC Data, 6 Byte 08 00 07 00 2A FC	10	16181
R	381 PDO	07 00 CE FF 0C 00 Data, 6 Byte 07 00 CE FF 0C 00	10	16181
R	481 PDO	E9 FF 21 00 E0 Data, 5 Byte E9 FF 21 00 E0	10	16181
R	581 SDO Server	60 10 10 01 00 00 00 00 [1010, 01] Init Download	9818	25
R	701 NMT	05 Operational	1000	77
T	000 NMT Master	81 00 Reset node, node 1 .. 127	0	1
T	601 SDO Client	23 10 10 01 73 61 76 65 [1010, 01] Init Download Exp., 4	9509	25


In addition, messages can be defined by the user which can be spontaneously or periodically sent from the HMG 4000 to further CAN participants.

5.1.3.4. Network Management (NMT)

With the sub-functions of the function "*Network Management*", the HMG 4000 can "simulate" the tasks of a *CANopen Masters* by providing the most important *NMT messages*.





Using the functions provided, the *NMT status* of the connected network participants can be changed.

5.2. PCAN-View

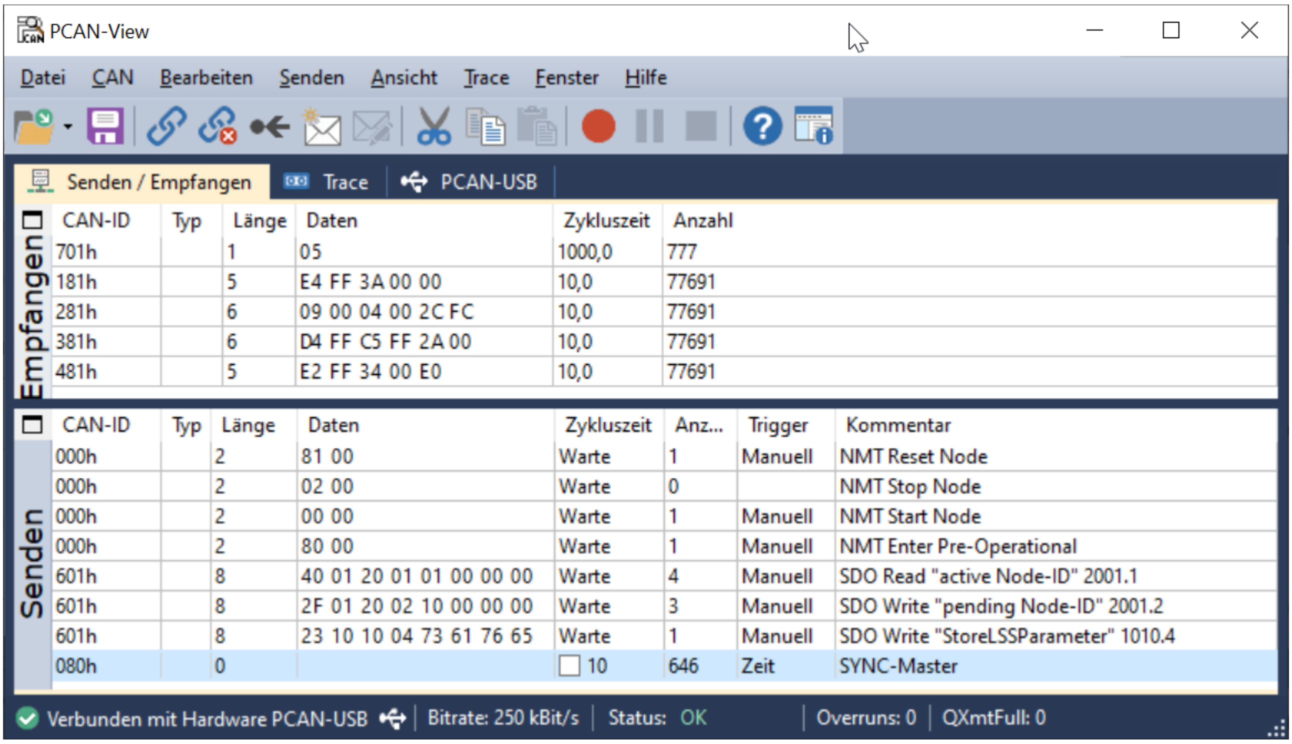
A widely used PC-based program for the visualisation of CAN messages is PCAN view by PEAK-System Technik GmbH.

PEAK-System Technik GmbH
Otto-Röhm-Straße 69
64293 Darmstadt
Germany

http://www.peak-system.com/

All rights to the product PCAN-View belong to the company PEAK-System Technik GmbH. In the following, a short insight is given into how easily CAN commands can be sent and received using this program. In addition to this, the program has further useful features which are worth discovering.

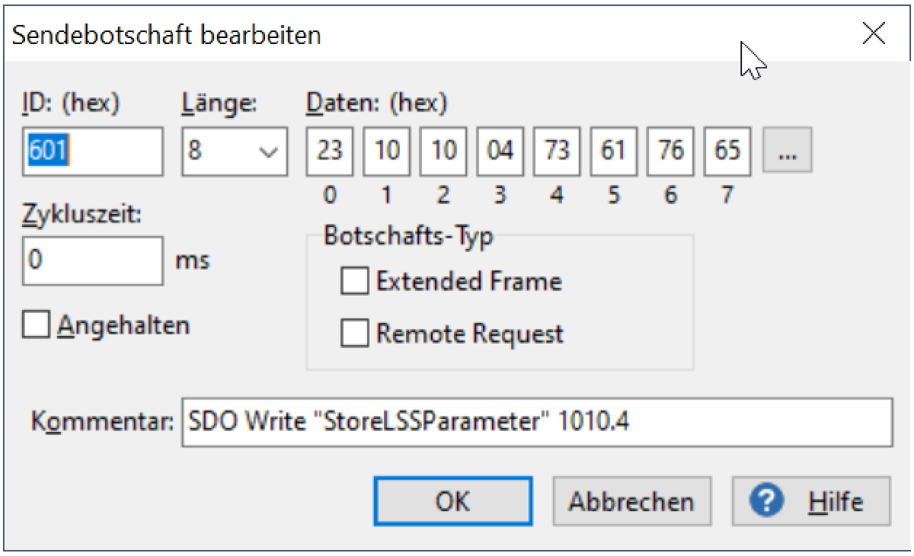
For more detailed information on the product itself or further products by this manufacturer, please do not hesitate to contact the manufacturer directly.



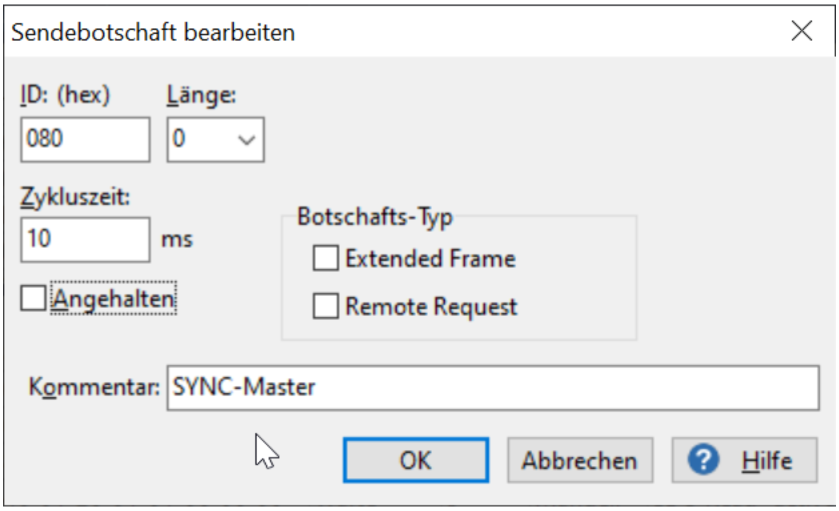
In the "receive“ section, all the messages currently waiting at the CAN are visualised grouped according to *CAN-ID*. In addition, the menu function "Trace" offers a chronological protocol of the messages. These protocols can also be stored in files.

In the "**Send"** section, there is also the opportunity to send *CAN message*. Several messages can be generated for this purpose, which can be spontaneously or periodically sent.

Example of the definition of a *CAN message* of a "*SDO expedited Download*" command from the object "*StoreLSSParameter*" with the help of which changes at the Node-ID or Baud rate of a device can be stored permanently. This message writes the *Character string* "save" with 4 bytes into the object 1010.4 in order to trigger the *Object function*. The structure of an SDO command is described in chapter *4.6.1.1 Structure of the* SDO command.



In order to create a periodically sent *CAN message*, as is necessary, for instance to simulate an *SYNC Master*, a cycle time of > 0 ms has to be assigned to the message.



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6. Contact Information

HYDAC ELECTRONIC GMBH

Hauptstr.27
D-66128 Saarbruecken

Germany

Web: www.hydac.com
E-mail: electronic@hydac.com
Phone: +49 (0)6897 509-01
Fax.: +49 (0)6897 509-1726

HYDAC Service

If you have any questions concerning repair work, please do not hesitate to contact HYDAC SYSTEMS & SERVICES GMBH:

HYDAC Systems & Services GMBH

Werk 14

Sonnenallee 1

Campus Göttelborn - Süd

D-66287 Quierschied-Göttelborn

Tel.: +49 (0)6897 509-1936

E-Mail: service@hydac.com

Annotation

The information in this manual relates to the operating conditions and applications described. For applications or operating conditions not described, please contact the relevant technical department.

If you have any questions, suggestions or encounter any problems of a technical nature, please contact your HYDAC representative.

7. Appendix

The appendix provides useful additional information.

7.1. ASCII Table

Below is a list of the portrayable characters of the ASCII character set. By combining the horizontal and vertical identification code, the numeric value belonging to the particular character can be determined. The ASCII character encoding forms the basis for most of the character sets used for a standardised representation of the most important characters.

Particular language-specific special characters, such as the **ß** which is part of the German written language, cannot be displayed using ASCII encoding. For the representation of these characters, there are special international character sets which will not be referred to herein, as special characters are not supported by the devices.

Examples

- Vertical: 30 + Horizontal: 2 = **32d** (20h), this is the numerical value for **blank /**<space>.
- Vertical: 60 + Horizontal: 5 = 65**d** (41h), this is the numerical value for **A** as a capital letter.

7.1.1. ASCII table in decimal representation

+	0	1	2	3	4	5	6	7	8	9
00	Control character									
10										
20										
30			<space>	!	“	#	$	%	&	‘
40	(	)	*	+	,	-	.	/	0	1
50	2	3	4	5	6	7	8	9	:	;
60	<	=	>	?	@	**A**	B	C	D	E
70	F	G	H	I	J	K	L	M	N	O
80	P	Q	R	S	T	U	V	W	X	Y
90	Z	[	\	]	^	_	`	a	B	c
100	d	e	f	g	h	i	j	k	l	m
110	n	o	p	q	r	s	t	u	v	w
120	x	y	z	{	|	}	~			

7.1.2. ASCII table in hexadecimal representation

Example.: "zero" → 7Ah, 65h, 72h, 6Fh

+	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**A**	**B**	**C**	**E**	**E**	**F**
00	Control character															
10																
20		!	“	#	$	%	&	‘	(	)	*	+	,	-	.	/
30	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
40	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
50	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
60	`	a	b	c	d	**e**	f	g	h	i	j	k	l	m	n	**o**
70	p	q	**r**	s	t	u	v	w	x	y	**z**	{	|	}	~	