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TURCK

CANopen Encoders
RS-107/108
RM-105/106

Manual

1 General

CANopen Singleturn/Multiturn Encoder Series RS-107/108 and RM-105/106
The RS-107/108, RM-105/106 CANopen encoders support the latest CANopen communication profile according **DS 301 V4.02**. In addition a device-specific encoder profile **DS 406 V3.2.16** is implemented.

The following operating modes can be selected: Polled Mode, Cyclic Mode, Sync Model. Moreover, scale factors, preset values, limit switch values and many other additional parameters can be programmed via the CAN-Bus. At Power ON all parameters are loaded from an EEPROM, which had previously been saved in the non-volatile memory to protect them in case of power failure. The following output values may be freely combined as PDO (PDO Mapping): position, speed as well as the status of the two limit switches.

A 2-color LED on the backside indicates the operating and error status of the CAN bus, as well as the condition of internal diagnostics. CANopen encoders are available both in shaft and hollow shaft versions; their IP 65 protection level allows using them even in tough industrial environments.

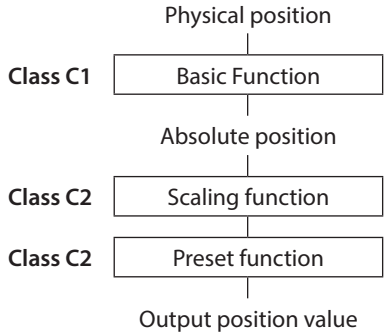
The CANopen Communication Profile DS 301 V4.2.0
CANopen represents a unified user interface and thus allows for a simplified system structure with a wide variety of devices. CANopen is optimized for the fast exchange of data in real-time systems and possesses a number of different device profiles that have been standardized. The CAN in Automation (CiA) manufacturers and users group is in charge of the creation and standardization of the relevant profiles.

CANopen offers
- user-friendly access to all device parameters.
- auto-configuration of the network and of the devices
- device synchronization within the network
- cyclic and event-driven process data exchange
- simultaneous read and write of data

CANopen uses four communication objects (COB) with different properties
- Process Data Objects (PDO) for real-time data
- Service Data Objects (SDO) for transmitting parameters and programs
- Network Management (NMT, Life-Guarding, Heartbeat)
- Predefined Objects (for Synchronization, Time-Stamp, Emergency)

All device parameters are filed in an Object dictionary. This Object Dictionary contains the description, data type and structure of the parameters, as well as the address (Index).
The dictionary is divided into a communication profile section, a section covering the device profile as well as a section specific to the manufacturer.

Encoder Device Profile DS 406 V3.1
This profile describes a vendor-independent mandatory definition of the interface with regard to encoders. It is laid down in the profile, which CANopen functions are to be used as well as how they are to be used. This standard thus makes possible an open vendor-independent bus system.
The device profile is broken down into two Object classes:



• **Class C1** describes all the basic functions that the encoder must contain

• **Class C2** contains numerous extended functions, which must either be supported by encoders of this class (Mandatory) or which are optional. Class 2 devices thus contain all C1 and C2 mandatory functions, as well as additional optional functions dependent on the manufacturer. An address range is also defined in the profile to which the manufacturer's own special functions can be assigned.

2 LSS services DS 305 V2.0

CiA DSP 305 CANopen Layer Setting Service and Protocol (LSS) were created to enable the following parameters to be read and changed through the network:

- Node address
- Baud rate
- LSS address

These features increase the "plug-and-play" compatibility of the device, while the configuration possibility has been significantly simplified. The LSS Master is responsible for configuring these parameters on one or more slaves on the network.

Data transmission
With CANopen data is transferred via two different communication types (COB=Communication Object) with different properties:

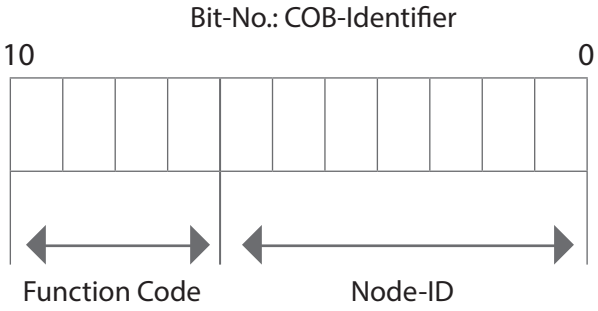
- Process Data Objects (PDO – real-time capable)
- Service Data Objects (SDO)

The Process Data Objects (PDO) provide highly dynamic exchange of real-time data (e.g. encoder position, speed, comparative position status) with a maximum length of 8 byte. This data is transmitted with a high priority (low COB-Identifier). PDOs are broadcast messages and provide their real-time data simultaneously to all desired receivers. PDOs can be mapped, i.e. 4 byte of position and 2 byte of speed can be combined in one 8 byte data word.

The Service Data Objects (SDO) form the communication channel for the transfer of device parameters (e.g. encoder resolution programming). As these parameters are transmitted acyclically (e.g. only once during boot-up of the network), the SDO objects have a low priority (high COB-Identifier).

Objects and Function Code in the Predefined Connection Set
For easier management of the Identifiers CANopen uses the "Predefined Master/Slave Connection Set", where all identifiers are defined with standard values in the object dictionary. These identifiers can be changed and customized via SDO access.

The 11-bit Identifier is made up of a **4-bit function code** and a **7-bit node-ID number.**



Note:
The higher the value of the COB-Identifier, the lower is its priority!

Broadcast (network-wide) Objects

Object	Function code (binary)	Resulting COB-ID	Communication Parameters at Index
NMT	0000	0	-
SYNC	0001	128 (80h)	1005h, 1006h, 1007h
TIME STAMP	0010	256 (100h)	1012h, 1013h

Peer-To-Peer (device-to-device) Objects

Object	Function code (binary)	Resulting COB-ID	Communication Parameters at Index
EMERGENCY	0001	129 (81h) - 255 (FFh)	1014h, 1015h
PDO1 (tx)	0011	385 (181h) - 511 (1FFh)	1800h
PDO1 (rx)	0100	513 (201h) - 639 (27Fh)	1400h
PDO2 (tx)	0101	641 (281h) - 767 (2FFh)	1801h
PDO2 (rx)	0110	769 (301h) - 895 (37Fh)	1401h
PDO3 (tx)	0111	897 (381h) - 1023 (3FFh)	1802h
PDO3 (rx)	1000	1025 (401h) - 1151 (47Fh)	1402h
PDO4 (tx)	1001	1153 (481h) - 1279 (4FFh)	1803h
PDO4 (rx)	1010	1281 (501h) - 1407 (57Fh)	1403h
SDO (tx)	1011	1409 (581h) - 1535 (5FFh)	1200h
SDO (rx)	1100	1537 (601h) - 1663 (67Fh)	1200h
NMT Error Control	1110	1793 (701h) - 1919 (77Fh)	1016h, 1017h

Restricted, Reserved Object

COB-ID	Used by object
0 (000h)	NMT
1 (001h)	reserved
257 (101h) - 384 (180h)	reserved
1409 (581h) - 1535 (5FFh)	default SDO (tx)
1537 (601h) - 1663 (67Fh)	default SDO (rx)
1760 (6E0h)	reserved
1793 (701h) - 1919 (77Fh)	NMT Error Control
2020 (780h) - 2047 (7FFh)	reserved

3 Process Data Transmission

The 4 PDO services PDO1 (tx) ,PDO2 (tx) … PDO4 (tx) are available for process data transmission. A PDO transmission can be triggered by a variety of events (see Object Dictionary Index 1800h):

- asynchronously (event driven) by an internal cyclic event timer or by a change in the process value of the sensor data
- synchronously as a response to a SYNC telegram; (a SYNC command will cause all CANopen nodes to store their values synchronously, after which they are transferred in succession to the bus according to their set priority)
- as a response to an RTR-Telegram (per Remote Frame=recessive RTR-bit, exactly that message with the communicated ID will be requested)

Standard setting for the **Mapping of the transmit PDOs1-4:**

Mapping	TPDO1 1800h	TPDO2 1801h	TPDO3 1802h	TPDO4 1803h
Mapping object	1A00h	1A01h	1A02h	1A03h
Entry	0x60040020	0x60040020	0x60300110	0x21600020 0x21620010
Object	6004h	6004h	6030h	2160h 2162h
Subindex	00	00	01	00
Data Length	20h (32 Bit)	20h (32 Bit)	10h (16 Bit)	20h (32 bits)
	Asynchronous	Synchronous	Asynchronous	Asynchronous

Transmit PDO 1 (1800h) Position asynchronous

Default COB-ID is 180 + Node number: e.g. 180h + 3Fh = 1BFh

Message	Byte 0	Byte 1	Byte2	Byte 3
1BF	Position LSB	XX	XX	Position MSB

The position values can have a maximum value of 0 – 2^{32} bits.

Transmit PDO2 (1801h) Position synchronous

Default COB-ID is 280 + Node number: e.g. 280h + 3Fh = 2BFh

Message	Byte 0	Byte 1	Byte2	Byte 3
2BF	Position LSB	XX	XX	Position MSB

The position values can have a maximum value of 0 – 2^{32} bits.

Transmit PDO3 (1802h) Speed asynchronous

Default COB-ID is 380 + Node number: e.g. 380h + 3Fh = 3BFh

Message	Byte 0	Byte 1
3BF	Speed LSB	Speed MSB

The speed value is signed and can have values in the range 0 – 1A00h or 0 – E600h.

4 Extended functionality CANopen Encoder Profile V3.2.16

In addition, the transmission can be set so as to include an additional CRC check sum with the raw position data with the help of mapping Object (1A03h or 1A04h). * (optional)

Transmit PDO4 (1803h) Raw position data from the sensor (32 bits) without scaling
Raw position data CRC16

Default COB-ID is 480 + Node number: Example 480h + 3Fh = 4BFh

Message	Byte 0	Byte 1	Byte 2	Byte 3	Byte 5	Byte 6
4BF	LSB	…	….	MSB	CRC_L	CRC_H

The position values can have a maximum value of 0 – 2^{32} bits.

5 Service Data Transmission

SDO-COB-ID
The following identifiers are available as standard for the SDO services:

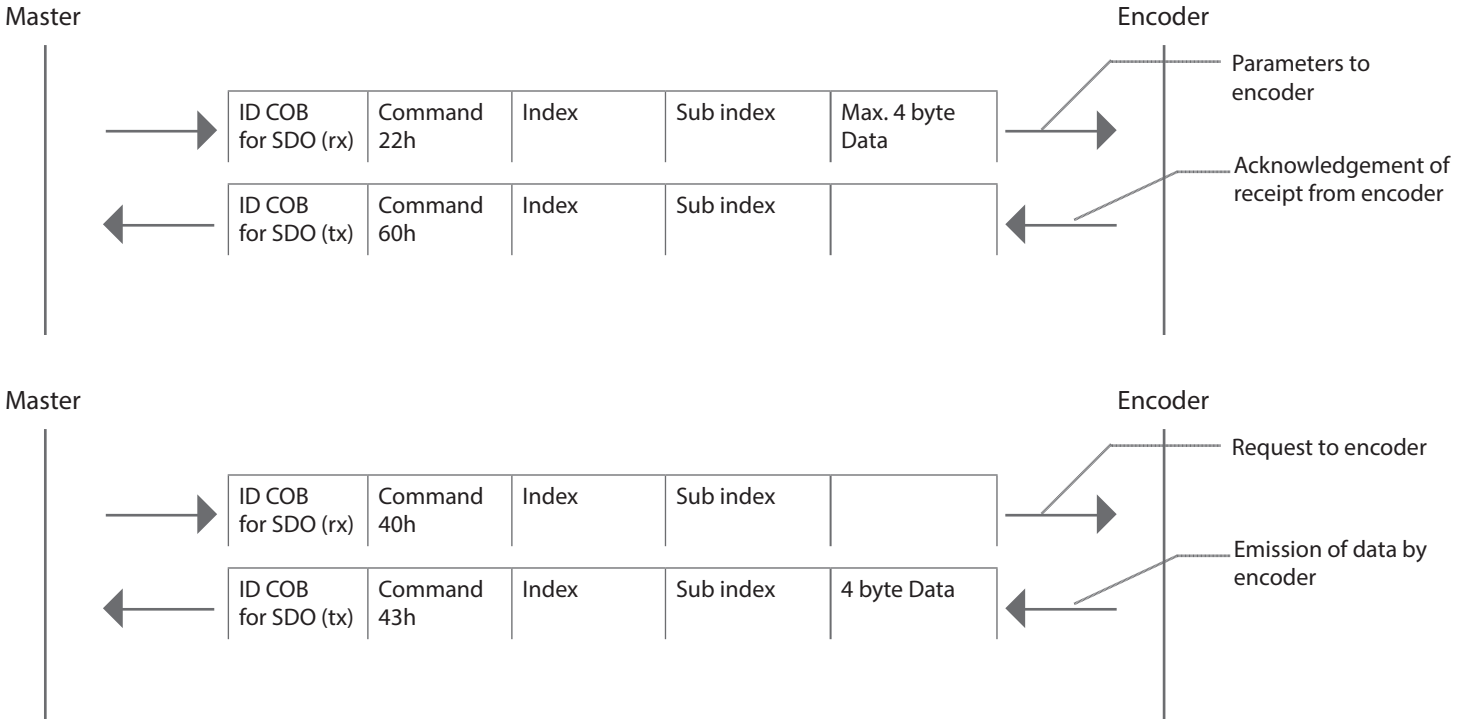
SDO (tx) (Encoder -› Master): 580h (1408) + node number
SDO (rx) (Master -› Encoder): 600h (1536) + node number
The SDO identifiers cannot be modified!

The command byte describes the type of the SDO message:

Command (Expedited Protocol)	Type	Function
22h	SDO(rx), Initiate Download Request	Send parameters to encoder (max. data length 4 byte)
23h	SDO(rx), Initiate Download Request	Send parameters to encoder (data length 4 byte)
2Bh	SDO(rx), Initiate Download Request	Send parameters to encoder (data length 2 byte)
2Fh	SDO(rx), Initiate Download Request	Send parameters to encoder (data length 1 byte)
60h	SDO(tx), Initiate Download Request	Acknowledgement of receipt by Master
40h	SDO(rx), Initiate Download Request	Request of parameters from encoder
43h	SDO(tx), Initiate Download Request	Parameters to Master, data length = 4 byte (unsigned 32)
4Bh	SDO(tx), Initiate Download Request	Parameters to Master, data length = 2 byte (unsigned 16)
4Fh	SDO(tx), Initiate Download Request	Parameters to Master, data length = 1 byte (unsigned 8)
80h	SDO(tx), Abort Domain Transfer	Encoder sends an error code to Master

Note:
An error message (Command 80h) replaces the normal (response) in case of an error. The error message includes as well communication errors (wrong command byte) as object dictionary access errors (wrong index, write attempt on a read-only object, wrong data length, etc.).
The error codes are described in the CANopen profile (DS 301) and in the device profile (DSP 406).

Example of a service data transmission to and from the encoder



6 LSS services

LSS Hardware Restrictions (LSS Address)
All LSS slaves must have a valid entry in the object dictionary for the Identity Object [1018h] in order to be able to carry out a selective configuration of the node. This Object is made of the following subindices:

- Vendor-ID (numerical number)
- Product-Code (numerical number)
- Revision-Number (major an minor revision as numerical number)
- Serial-Number (numerical number)
- LSS-Master CAN-ID 2021
- LSS-Slave CAN-ID 2020

A product code, a revision number and a serial number are set by the manufacturer. The LSS address must be unique in the network.

LSS Operating Restrictions
In order to ensure a perfect LSS functionality, all devices in the network must support the LSS services. There can only be one LSS master. All nodes must be started up with the same baud rate.
LSS communication can only take place in "Stop" mode or in "Pre-Operational" mode.

7 CAN-Bus connection M12 connector

Cable						
Signal:	0V power supply	+V power supply	CAN_Low (-)	CAN_High (+)	CAN Ground	Bus IN
Abbreviation:	0V	+V	CL	CH	CG	
Cable Color:	WH	BN	YE	GN	GY	

2 x M12 connectors							
Signal:	0V power supply	+V power supply	CAN_Low (-)	CAN_High (+)	CAN Ground	Bus IN	Bus OUT
Abbreviation:	0V	+V	CL	CH	CG		
Pin:	3	2	5	4	1		

1 x M12 connectors						
Signal:	0V power supply	+V power supply	CAN_Low (-)	CAN_High (+)	CAN Ground	Bus IN
Abbreviation:	0V	+V	CL	CH	CG	
Pin:	3	2	5	4	1	

Signal description	Notation
CAN_L bus line (dominant low)	CAN_L or CAN_{low} or CANCAN_
H bus line (dominant high)	CAN_H or CAN_{high} or CAN+
CAN ground	CAN_GND or CAN_{GND} or Ground or GND
Optional CAN shield	CAN_SHLD or CAN_{SHIELD} or Shield or SHLD
Optional CAN external positive supply	CAN_V+ or CAN_{V+} or V+ or UC or U_{CAN}
Optional ground	OPT_GND or GND_{opt} or V- or 0 V

8 Initial Startup - General Device Settings

Baud rate
The baud rate can be modified either with a CANopen software on Object 2100h or via the corresponding LSS service.

Factory default: 250 kBit/s (value 5)

Value	Baud rate in KBit/s
0	10
1	20
2	50
3	100
4	125
5	250
6	500
8	1000

To be considered for the corresponding baud rate

The selected cycle time (see Object 1800h, subindex 5 Event timer) must be larger than the duration of the bus transmission in order to allow an error-free PDO transmission!

With a baud rate of 10 KBaud: cycle time must be at least 14 ms
With a baud rate of 20 KBaud: cycle time must be at least 10 ms
With a baud rate of 50 KBaud: cycle time must be at least 4 ms

Node number
The node number can also be modified by software on Object 2101h or via the corresponding LSS service.
Default Setting: 0x3F (63 decimal).
Node number 0 is reserved and may not be used by any node. The resulting node numbers lie in the range 1...7Fh hexidecimal (1...127 decimal).

Note:
The acceptance of a new node number only becomes effective when the encoder is rebooted (Reset/Power-on) or by means of an NMT Reset Node command.
All settings in the object table are reset to their standard/default value.

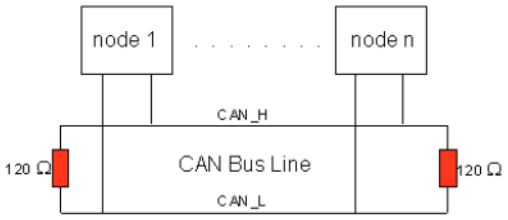
Save All Bus Parameters (2105h)

This parameter (Object 2105h) stores the desired bus parameters (Object 2100h, 2101h, 2102h) permanently in the Flash memory. This object is an additional protection against unintentional baud rate or node address modifications.

Only the targeted storage using parameter "save" (hexadecimal 0x65766173) saves the bus parameters baud rate, node address and termination permanently.

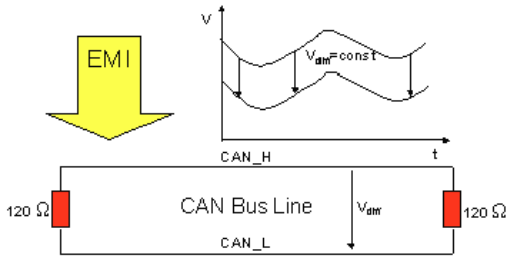
Important:
After the modification of the bus parameters and the subsequent storage with command 2105h, the application parameters must be re-programmed and saved again using Object 1010h.
Object 1010h does not save the bus parameters.

Termination



Default setting: 0x01 (bus termination active)

CAN is a 2-wire bus system to which all participants are connected in parallel (i. e. with short stub lines.) The bus must be terminated at both ends with a bus termination resistor of 120 (or 121) ohms in order to avoid reflections. This is also necessary even for very short line lengths!



The **CAN bus termination** must be set **by software on Object 2102h.**

Since the CAN signals are represented on the bus as differential levels, the CAN line is comparatively insensitive to interference (EMI). Interferences always affect both lines, and therefore they almost do not modify the differential level.

Bus length
With CAN, the maximum bus length is mainly limited by the signal propagation time. The multimaster bus access procedure (arbitration) requires an almost simultaneous presence of the signals (for the duration of one before scanning) at all nodes. Since the signal propagation time is almost constant in the CAN connections (transceiver, optocoupler, CAN controller), the line length must be adapted to the baud rate.

Baud rate	Bus length
1 MBit/s	< 20 m*
500 kBit/s	< 100 m
250 kBit/s	< 250 m
125 kBit/s	< 500 m
50 kBit/s	< 1000 m
20 kBit/s	< 2500 m
10 kBit/s	< 5000 m

*) the length of 40 m for 1 MBit/s is often quoted in the literature for CAN. However, this does not apply to networks with optodecoupled CAN controllers. The worst-case calculation with optocouplers gives, for 1 MBit/s, a maximum bus length of 5 m - experience shows however that 20 m can be reached without problem.

For bus lengths exceeding 1,000 m, the use of repeaters may become necessary.

9 Layer Setting Services (LSS)

Exactly two conditions must be met for devices to be connected to a CANopen network - all devices must have the same baud rate and every device must have a unique node address within the network. The condition for a use under LSS is that there is a 1:1 CAN connection with the device. A special dialogue mode then allows modifying the baud rate and node address. COB-ID 0x7E5 is sent from the master to the slave, the slave answers with COB-ID 0x7E4. LSS messages are always 8-byte long. Unused bytes are reserved and should be filled with 0.

A "Switch Mode Global" command is sent to switch a device in LSS configuration mode:

0x04	0x01	reserved

Unfortunately, this command is not confirmed, and only a visual check of the LEDs allows making sure that the device really switched to this mode.

The following command calls for the "Inquire Node-ID" service.

0x5E	reserved

If the command was carried out successfully, the slave answers with:

0x5E	Node ID	reserved

If no feedback answer is received from the device, the LSS service may not be supported, or the baud rate may be incorrect.

The "Configure Node-ID" command is used to re-configure the node address:

0x11	Node ID	reserved

The error code is included in the answer of the slave device:

0x11	Error code	Error extension	reserved

Error code 0 means that the command has been accepted - Error code 1 indicates an invalid Node ID.
The remaining error codes are reserved. The error extension includes manufacturer-specific information can only be used in case of error code 0xFF.

The baud rate is activated with the command "Configure Bit Timing Parameters".

0x13	Bit timing	Table entry	reserved

The following baud rates are standardized by CiA:

Baud rate table 0x00	
Table index	Baud rate
0	1000 kBit/s
1	800 kBit/s *not supported
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

Again, the device answers with an error code:

0x13	Error code	Error extension	reserved

Error code 0 means that the command has been accepted - Error code 1 indicates an invalid Node ID.
The remaining error codes are reserved. The error extension includes manufacturer-specific information can only be used in case of error code 0xFF.

Both network-specific parameters have now been modified, and the new parameters must be saved using “Store Configuration”:

0x17	reserved

Again, the device answers with an error code:

0x17	Error code	Error extension	reserved

Error code 0 means that the command has been accepted - Error code 1 indicates an invalid Node ID.
The remaining error codes are reserved. The error extension includes manufacturer-specific information can only be used in case of error code 0xFF.

To complete the LSS service, the device is switched back from the LSS configuration mode to the Preoperational mode with the command “Switch Mode Global”:

0x04	0x00	reserved

The device performs automatically a new boot-up (Reset node), after which all new settings become valid.

10 Default settings on delivery

Devices with cable outlet

Description	Setting	Software
Baud rate	250 Kbit/s	Object 2100h = 05h
Node address	63	Object 2101h = 3Fh
Termination	ON	Object 2102h = 01h

Communication parameters

Index (hex)	Name	Standard value
1005h	COB-ID Sync	80h
100Ch	Guard Time	0
100Dh	Life Time Factor	0
1012h	COB-ID Time stamp	100h
1013h	High Resolution time stamp	0
1016h	Consumer Heartbeat time	Node-ID 0, Time=0
1017h	Producer heartbeat time	0
1029h	Error Behavior	0 = Comm Error
		1 = Device specific
		1 = Manufacturer Err.
1800h	TPDO1 Communication Parameter	
01h	COB-ID	180h + Node number
02h	Transmission Type	255 (asynch)
03h	Inhibit Time	0 [steps in 100µs]
05h	Event timer	0 [steps in ms]
1801h	TPDO2 Communication Parameter	
01h	COB-ID	280h + Node number
02h	Transmission Type	1 (synch)
03h	Inhibit Time	0 [steps in 100µs]
05h	Event timer	0 [steps in ms]
1802h	TPDO3 Communication Parameter	
01h	COB-ID	380h + Node number
02h	Transmission Type	255 (asynch)
03h	Inhibit Time	0 [steps in 100µs]
05h	Event timer	0 [steps in ms]
1803h	TPDO4 Communication Parameter	
01h	COB-ID	101h-13Fh
02h	Transmission Type	255 (asynch)
03h	Inhibit Time	0 [steps in 100µs]
05h	Event timer	0 [steps 1ms]
1A00h	TPDO1 Mapping	
01h	1.Mapped Object	0x60040020

1A01h	TPDO2 Mapping	
01h	1.Mapped Object	0x60040020
1A02h	TPDO3 Mapping	
01h	1.Mapped Object	0x60300110
1A03h	TPD04 Mapping	
01h	1.Mapped Object	0x21600020
	2.Mapped Object	0x21620010

Encoder Profile

Index (hex)	Name	Standard value
6000h	Operating Parameter	0x00 Scaling off
6001h	Measuring Units per Revolution	2^{16} bits
6002h	Total Measuring Range	2^{32} bits (singleturn 2^{16})
6003h	Preset value	0
6200h	Cyclic Timer (see TPDO1 Comm.Par)	0
6031h	Speed Parameter	
	Speed Source Selector	2
	Speed Integration Time	100
	Speed Calc Multiplier	1
	Speed Calc Divisor	1
6401h	Work area low limit	0
6402h	Work area high limit	Max. Resolution
650Dh	Absolute Accuracy	13 bits
650Eh	Device Capability	3
2100h	Baud rate	5
2101h	Node number	0x3F
2102h	CANbus termination	1 (active)
2105h	Save All Bus Parameters	0x65766173
300Ah	Password-protected Area	
300Bh	Serial Number	

Important:

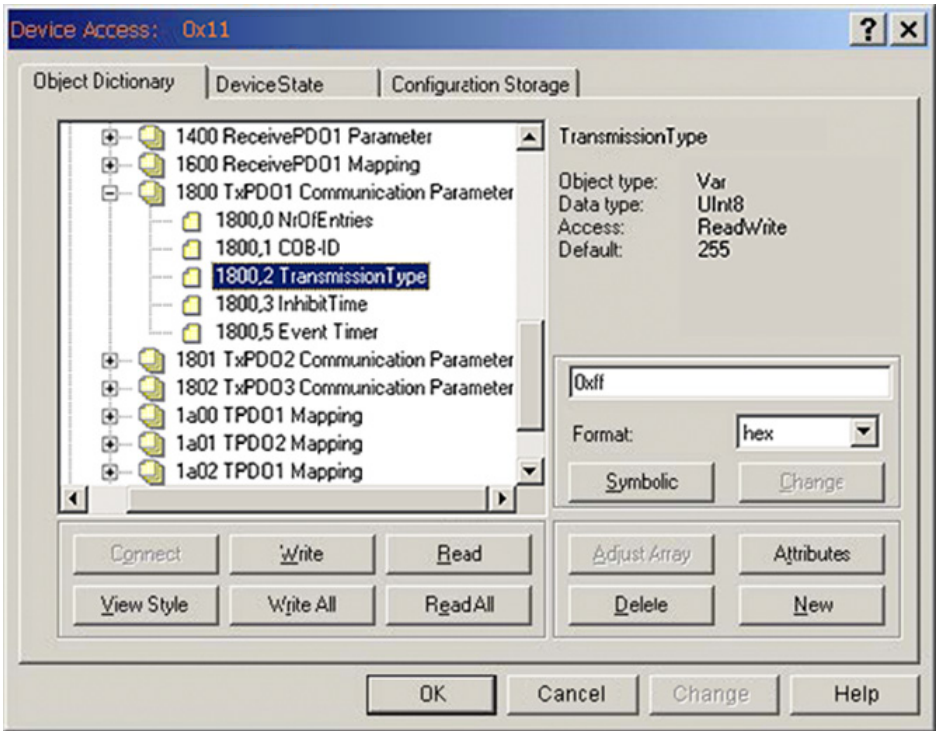
The original standard values (default values on delivery) can be reloaded using Object 1011h (Restore the parameters) with the indication "load" (0x6C6F6164).

Note:

In order to save the modified parameters against power failures, they must be transferred in the FLASH MEMORY using Object 1010h. This operation will overwrite all data previously stored in the FLASH MEMORY!

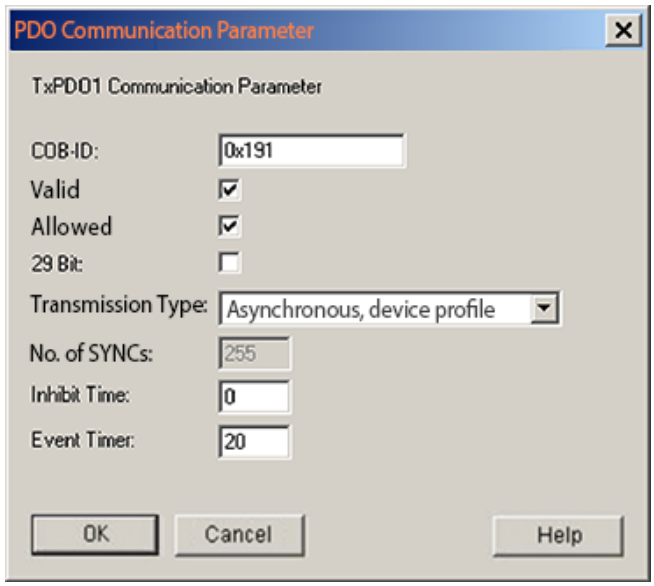
11 Communication Parameters

The COB-ID and the Transmission Type for PDO1 are defined in the Object Dictionary Index 1800h.

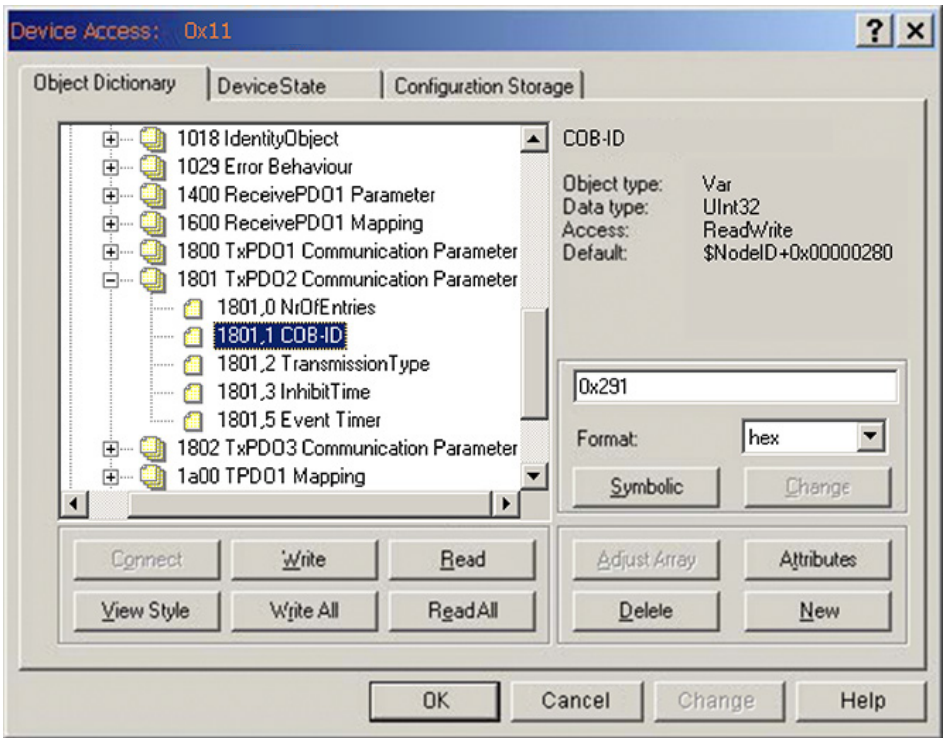


Default-settings:

Release:	PDO valid (enabled) RTR enabled
COB-ID:	180h + set node number (here 11h)
Transmission type:	255 = asynchronous acc. to device profile
Event Timer:	20 ms

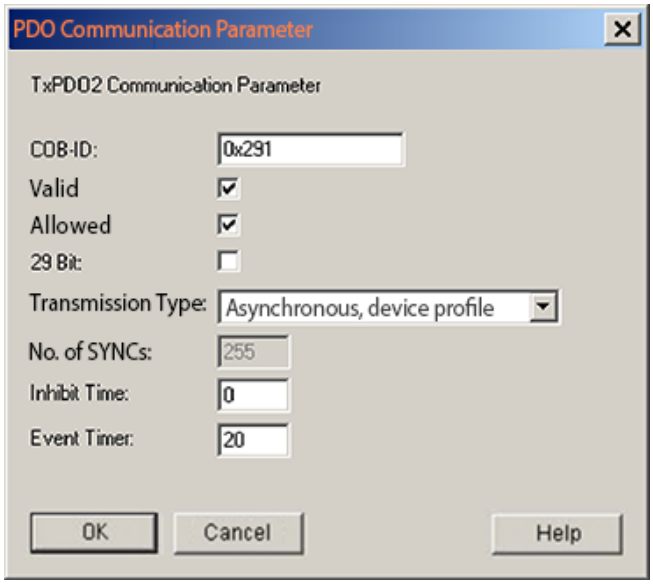


The COB-ID and the transmission type for PDO2 are defined in the object dictionary index 1801h.



Default settings:

Release:	PDO valid (enabled) RTR enabled
COB-ID:	280h + set node number (here 11h)
Transmission type:	255 = asynchronous acc. to device profile
Event Timer:	20 ms



Definition of the Transmission type of the PDO

transmission type	PDO transmission				
	cyclic	acyclic	synchronous	asynchronous	RTR only
0		X	X		
1-240	X		X		
241-251	- reserved -				
252			X		X
253				X	X
254				X	
255				X	

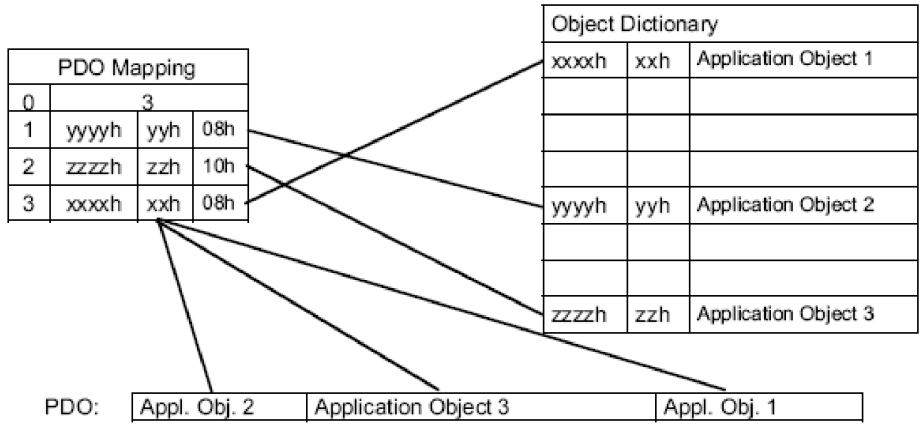
A value between 1 ...240 means that the PDO will be sent synchronously and cyclically. The number of the Transmission Type signifies the quantity of SYNC pulses that are necessary to forward the PDOs.
The Transmission Types 252 and 253 state that the PDO will only be sent when requested via an RTR.

Note:
Type 254 means that the event will be triggered depending on the application (application-specific), whereas Type 255 is dependent on the device (device-specific). Additionally for Numbers 254/255 a time-controlled EventTimer can be used. The values for the timer can range from 1ms ... 65535 ms.

Variable PDO Mapping

Variable Mapping of the various objects means that the user is able to configure the content of the Transmit PDOs dependent on the application.

Example of an entry in the Mapping Table:
The mapped PDO consists of 3 Application Object entries of varying lengths:

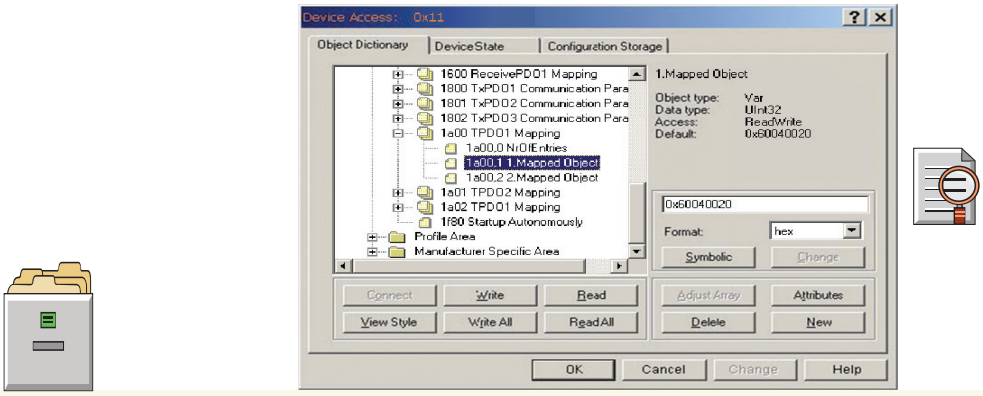


Application Object 2 occupies Byte 1 (08h) in the Transmit PDO. Thereafter follows Application Object 3 with a length of 16 bit (10h = 2 bytes) and finally Application Object 1 with a length of 1 byte. In total, 32 bits are occupied in this PDO.

12 Example of a variable mapping entry

Mapping Object 1A00h

Mapping object 1A00h describes the first transmit PDO. Objects may be mapped until the maximum data length of 8 bytes is reached. Similarly, object 1A01h describes PDO2 and 1A02h describes PDO3.



Mapping	TPDO1 Mapping	TPDO1 Mapping	TPDO1 Mapping
Subindex	00	01	02
Entry	Nbr of entries	1st mapped object	2nd mapped object
Object	2	6004h	6030h
Subindex		00	01
Data length	Byte	20h(32 Bit)	10h(16 Bit)
		Asynchron	Asynchron

The following objects can be mapped: (indicated in blue)

Device-**specific objects**

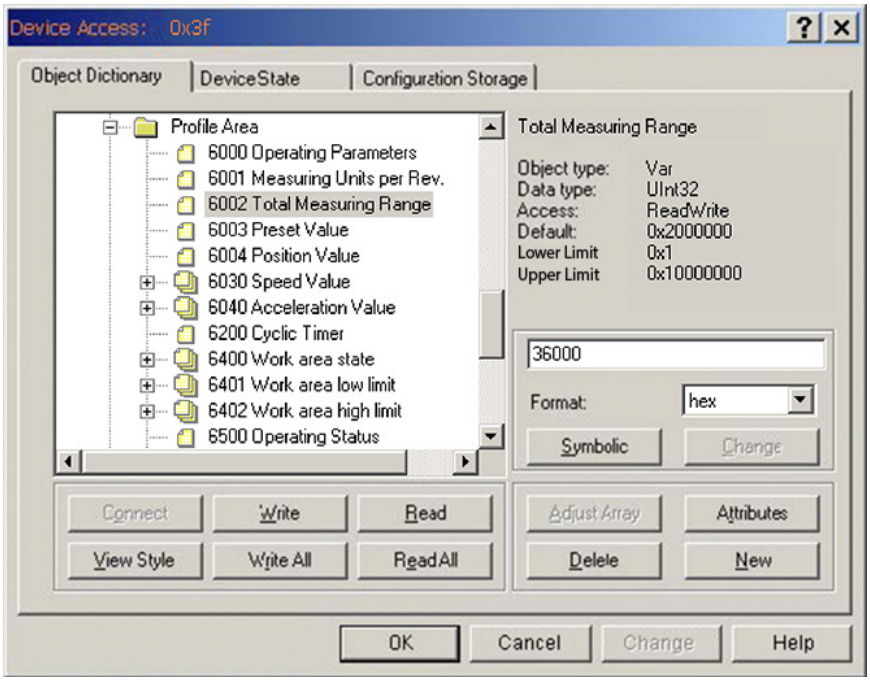
INDEX (hex)	Object Symb.	ATTRIB	Name	M/O C2	TYPE
6000	VAR	RW	Operating parameters	M	unsigned16
6001	VAR	RW	Measuring Units p.Revolution (MUR)	M	unsigned32
6002	VAR	RW	Total Measuring Range (TMR)	M	unsigned32
6003	VAR	RW	Preset value	M	unsigned32
6004	**VAR**	**RO**	**Position value**	**M MAP**	**unsigned32**
6030	**ARRAY**	**RO**	**Speed Value**	**O MAP**	**signed16**
6040	ARRAY	RO	Acceleration Value	O	Signed16
6200	VAR	RW	Cyclic Timer	M	unsigned16
6400	**ARRAY**	**RO**	**Working Area state**	**O MAP**	**unsigned 8**
6401	ARRAY	RW	Working Area Low Limit	O	Unsigned32
6402	ARRAY	RW	Working Area High Limit	O	Unsigned32
6500	VAR	RO	Operating Status	M	unsigned16
6501	VAR	RO	Measuring Step (Singleturn)	M	unsigned32
6502	VAR	RO	Number of revolutions	M	unsigned16
6503	**VAR**	**RO**	**Alarms**	**M MAP**	**unsigned16**
6504	VAR	RO	Supported alarms	M	unsigned16
6505	**VAR**	**RO**	**Warnings**	**M MAP**	**unsigned16**

In this example, 2 process data objects, 6004h and 6030h, are mapped.

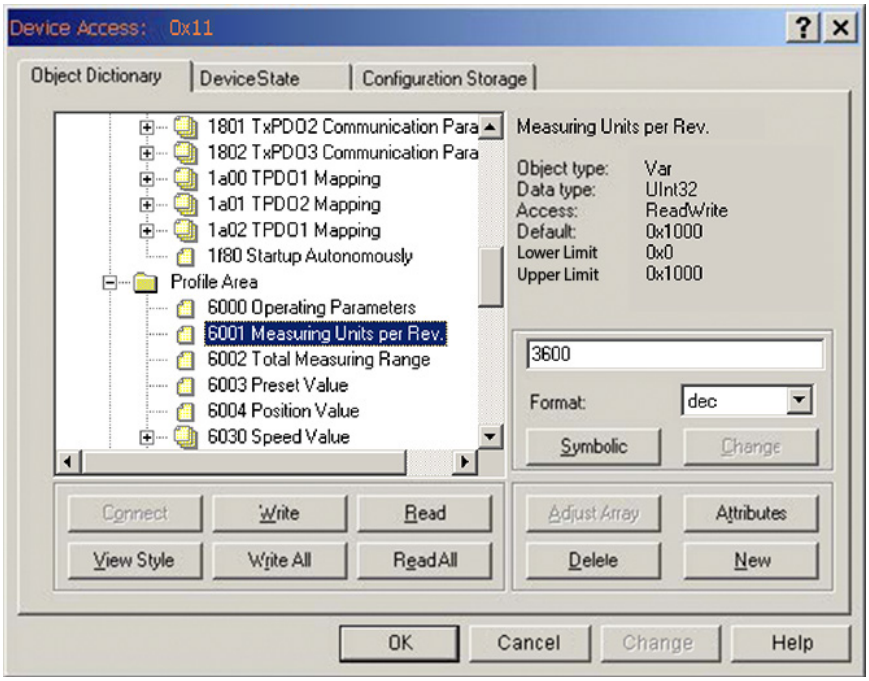
Programming example of an application:
Objects set-up

- Limit Total Measuring Range to 36000
- Measuring Units per Revolution must be set to 3600 steps per revolution
- Position value must be set to 0
- TPDO1 (Position) must be sent by 10 ms events
- TPDO2 (Speed) must be sent by 20 ms events
- Producer Heartbeat must be reduced to 500 ms
- Work area Limit values are 1000 and 35000
- The new parameters must be saved in the FLASH MEMORY

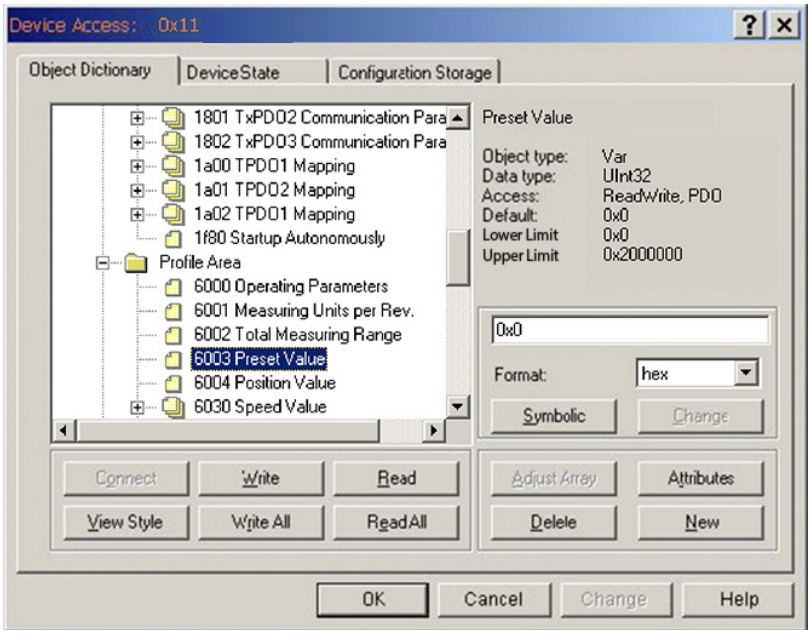
Limiting Total Measuring Range to 36000



Limiting Measuring Units per Revolution to 3600



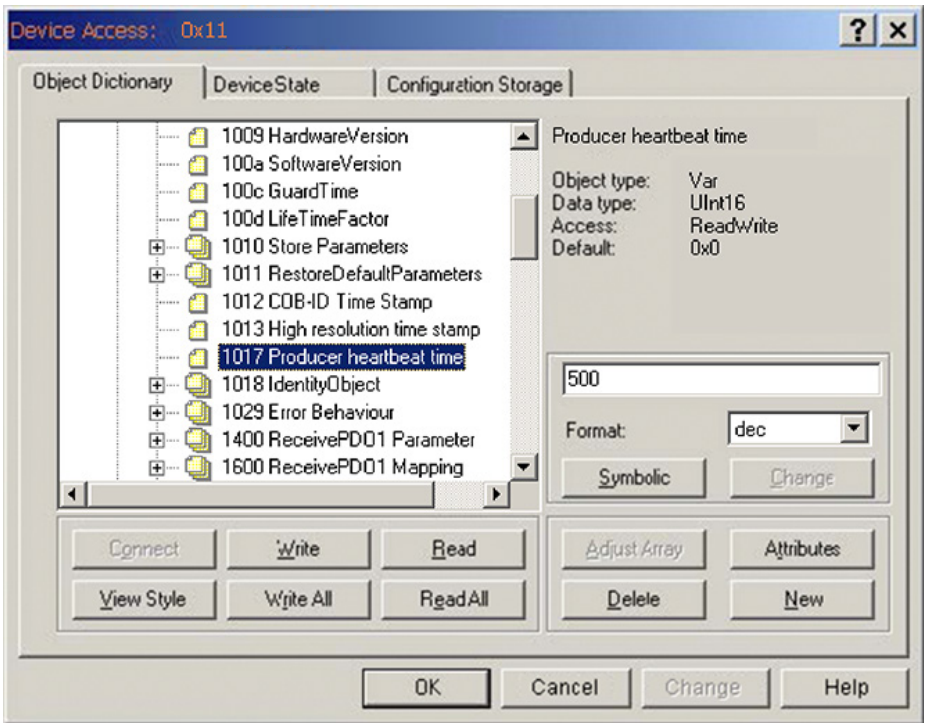
Preset value to 0



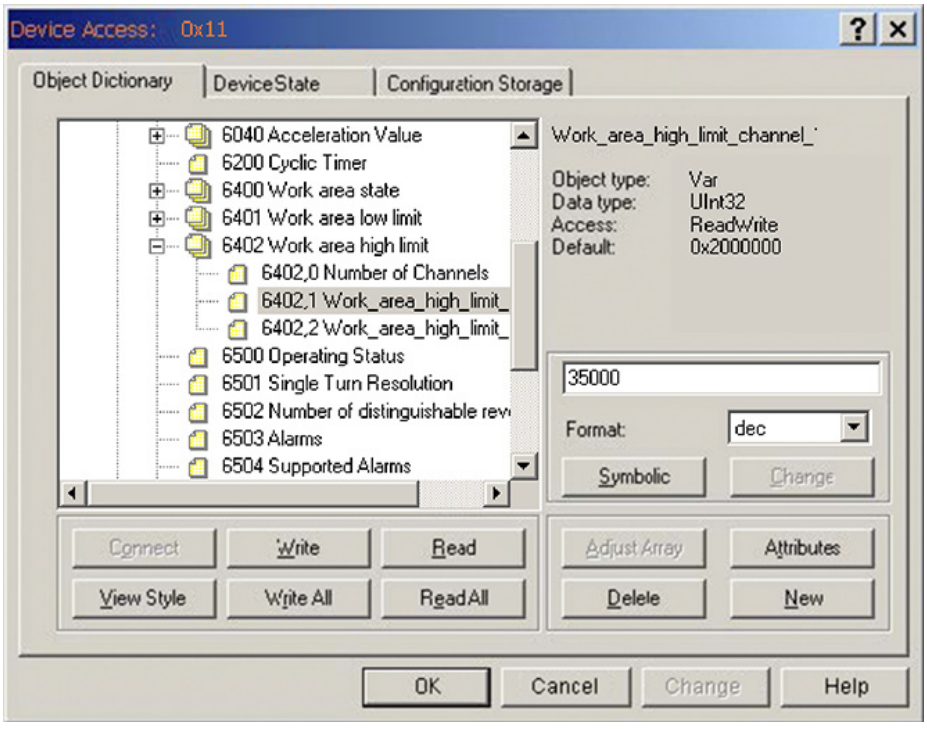
Definition off the values off transmit parameters TPDO1 and TPDO2

Type 254 indicates an application-dependent triggering of the event, while number 255 indicates a device profile-dependent triggering. In addition, a time-controlled EventTimer may be used for numbers 254/255. The value range for the timer reaches from 1 ms ... 65535 ms.

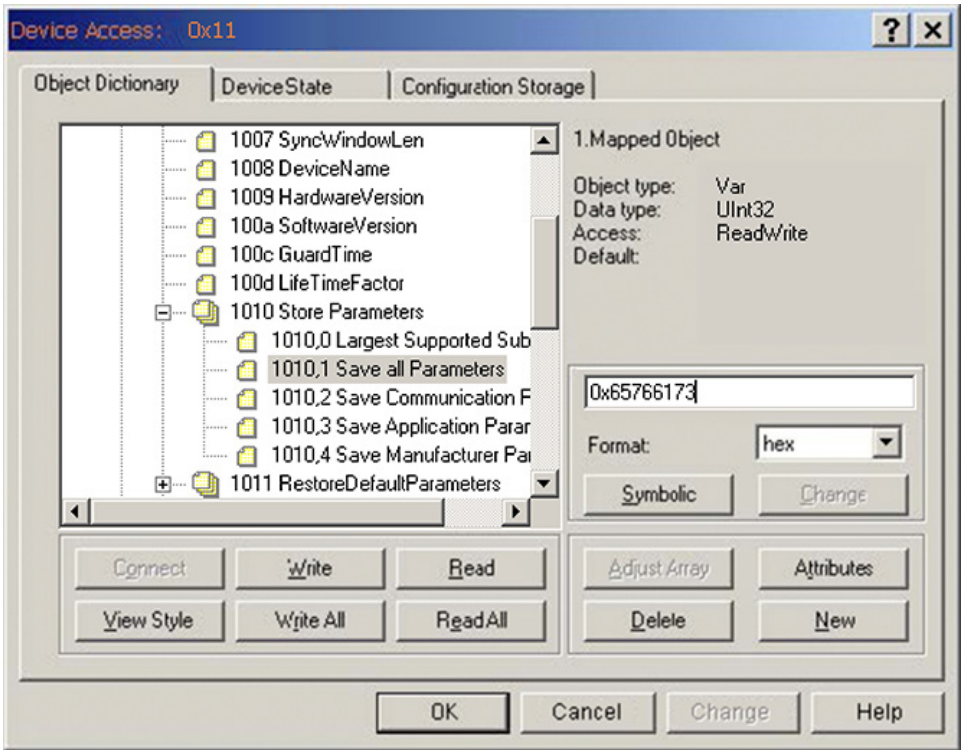
Setting Producer Heartbeat to 500 ms



Defining the Work area Low and High Limit values



Saving all modified parameters in the Flash memory
Store Parameters 1010h



Object 1010h Store Parameters
Command "save" under subindex 1h (save all Parameters) stores the parameters in the non-volatile memory (FLASH MEMORY).
This sub-item stores all communication objects, application objects and manufacturer-specific objects. This operation requires about 14 ms.

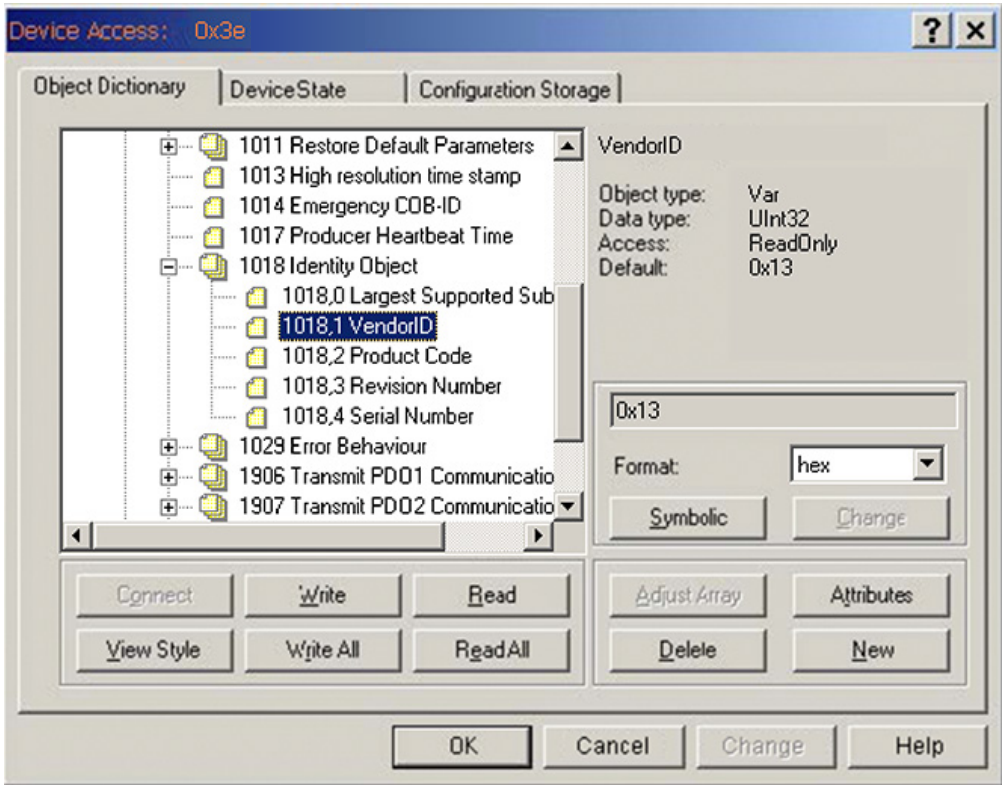
In order to avoid any unintentional storage, the command is only carried out when the string "save" is entered as code word in this subindex.
A read access to subindex 1h provides information about the memory functionality.

Byte 0: 73h (ASCII-Code for "s")
Byte 1: 61h (ASCII-Code for "a")
Byte 2: 76h (ASCII-Code for "v")
Byte 3: 65h (ASCII-Code for "e")

Object 1011h: Load standard values
The command "load" under subindex 1h resets all parameters to their standard values. In order to avoid any unintentional loading of the standard values, the command is only carried out when the string "load" is entered as code word in this subindex.

Byte 0: 6Ch (ASCII-Code for "l")
Byte 1: 6Fh (ASCII-Code for "o")
Byte 2: 61h (ASCII-Code for "a")
Byte 3: 64h (ASCII-Code for "d")

Communication profile - further objects
Object 1018h: Identity Object



Information about the manufacturer and the device:

Note:
1018 RECORD Device – Identification read only
Sub-Index 0h : Number of Subindices
returns the value 4

Sub-Index 1h: "read" only
returns the Vendor-ID (00000009Ch) Turck

Subindex 2h: returns the Product Code
(e. g. 0x56682001 CANopen encoder)

Sub-Index 3h: "read" only
returns the software revision number
(e. g. 108)

Sub-Index 4h: "read" only
returns the 11-digit **Serial number** of the encoder

13 Speed output configuration

The rotational speed of the encoder shaft is determined as the value difference between two physical (unscaled) position values with a dynamic time interval of 1ms, 10 ms or 100ms, or 200ms (Object 6031h).
To adapt the speed measurement to the concerned application, the operator can use 3 parametrizable objects in the manufacturer-specific area. In case of high speeds, the integration time of the measurement can be reduced to achieve accordingly high dynamics. The number of mean values especially affects the dynamics of the measurements; it must be determined according to the application.

Speed measurement accuracy
The accuracy of the measurement depends mainly of the following parameters:

- actual speed
- temporal speed change (internal dynamics)

Object 6031h: Speed gating Time (values for speed measurement)
The speed is calculated according to the following formula:

$$\text{Speed} = \frac{\text{Position change}}{\text{Integration time}} \times \text{Units factor}$$

For the units factor, parameters are available under Object 6031, sub3 (Speed Calculation Multiplier) and under Object 6031,sub4 (divisor). Speed output either in RPM or as a number of steps per second in Object 6000h Bit 13.

Parameter Object 6031,sub3 (Speed Measuring Multiplier) can contain e. g. the periphery of a measuring wheel in order to affect the speed.

Important:
Under Objects 6031, sub3/4, only the speed output with the unit [unit/sec] may be affected, the RPM output is not parametrizable.

14 Emergency Message

Emergency Objects arise in case of error situations within a CAN network and are triggered depending on the event and transmitted over the bus with a high priority.
Important: an Emergency Object is only triggered once per "Event". No new object is generated as long as the error is active. Once the error is eliminated, a new Emergency Object with the content 0 (Error Reset or No Error) is generated and transmitted over the bus.

Byte	0	1	2	3	4	5	6	7
Content	Emergency Error Code		Error register (Object 1001H)	Manufacturer specific Error Field				

The behavior in case of an error is described in Object 1029h Error Behavior

Example of a message for overtemperature:

Transfer Data	00	42	09	80	56	20	50	2E

[Errcode]		4200 Sensor temperature threshold value exceeded
[Error Register]	09	Error register
[ManufacturerSpecific1]	80	ICLG Error register
[ManufacturerSpecific2]	56	ICLG momentary temperature
[ManufacturerSpecific3]	20	ICLG current threshold value lower range
[ManufacturerSpecific3]	50	ICLG current threshold value higher range
[ManufacturerSpecific5]	2E	ICLG Version register

15 Implemented Error Codes

Error Code	Error register	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Remarks
5200	01	09	81	45	00	00	ICLG Optic Failure
		81					ICLG Error Mask Register
		45					ICLG Error Register
4200	01	07	81	A8	20	A2	System Temperature Error
		81					ICLG Error Register
		A8					ICLG Temperature Register
		20					ICLG Temperature Lower Reg
		A2					ICLG Temperature Upper Reg
3200	01	02	6A	01	00	00	System Battery Low Error
		6A					Battery low voltage (LSB)
		01					Battery Low voltage (MSB)
3200	05	02	00	00	00	FF	Battery cable damage
8110	11	00					CAN Overrun Error
8120	11	00					CAN Passive Error Mode
8130	01	00					Life Guard or Heartbeat Error

Object 1016h: Consumer Heartbeat Time
If this function is to be activated, a valid node ID to be monitored, with a corresponding time, must be entered in Object 1016h,Subindex 1 and/or 1016h,Subindex 2.
The time entered must always be larger than the Heartbeat Producer time that is to be monitored.
The function is active upon a boot-up cycle, provided the entered data has been saved.
(Store parameters object 1010h).

Note:
Monitoring is started after the first occurrence of a Heartbeat with the corresponding node ID. If a 0 ms time is entered, the function is inactive.
Valid settings: 1ms up to max. 65535 ms

	MSB		LSB
Bits	31-24	23-16	15-0
Value	reserved (value: 00h)	Node-ID	heartbeat time
Encoded as	-	UNSIGNED8	UNSIGNED16

Figure 62: Structure of Consumer Heartbeat Time entry

OBJECT DESCRIPTION

INDEX	1016h
Name	Consumer Heartbeat Time
Object Code	ARRAY
Data Type	UNSIGNED32
Category	Optional

ENTRY DESCRIPTION

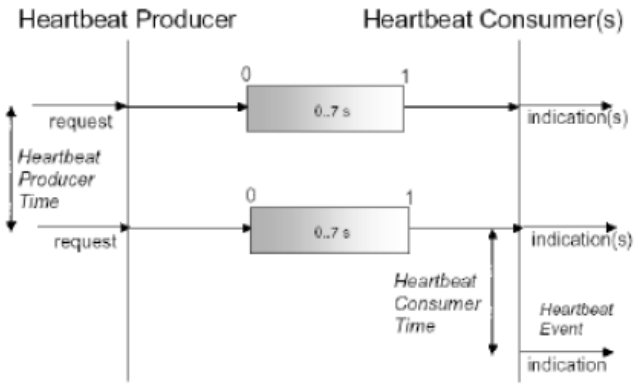
Sub-Index	0h
Description	number entries
Entry Category	Mandatory
Access	ro
PDO Mapping	No
Value Range	1 – 127
Default Value	No

Sub-Index	1h
Description	Consumer Heartbeat Time
Entry Category	Mandatory
Access	rw
PDO Mapping	No
Value Range	UNSIGNED32 (Figure 62)
Default Value	0

Sub-Index	2h – 7Fh
Description	Consumer Heartbeat Time
Entry Category	Optional
Access	rw
PDO Mapping	No
Value Range	UNSIGNED32 (Figure 62)
Default Value	No

Note:
Two nodes with node ID and corresponding time setting are supported.

Entries with different times for one node ID and changes of the entries without previously erasing the values with 0 are answered with an abort code 0604 0043h (General parameter incompatibility reason).



One or several Heartbeat Consumers receive the Producer's message. If this message is missing for any reason after the time set for the Consumer has elapsed, a "Heartbeat Event" is generated.

The Heartbeat Consumer device activates an emergency message with an error code "8130 Lifeguard or heartbeat". Depending on the setting of Error behavior Objects1029h,Sub 1, the Consumer switches back to Preoperational state when this error appears. The behavior is therefore determined by Object 1029h Subindex 1 "Communication Error".
(0 = switch to Preop, 1= no state change)

Configuration example:

Time

	MSB		LSB
Bits	31-24	23-16	15-0
Value	reserved (value: 00h)	Node-ID	heartbeat time
Encoded as	-	UNSIGNED8	UNSIGNED16

Object 1016, 1 h:
Consumer Heartbeat.

Sample string:	00	07	1F4	= 0x000701F4

Monitored device Node 07 Time = 500 ms
In case of an error, the following emergency message is generated:

Transfer Data	30	81	11	00	00	00	00	00

[Errcode]	8130	Life Guard or Heartbeat error
[Error Register]	11	Error Register
[ManufacturerSpecific1]	00	ICLG error register

Note:
A NMT "Reset-Node Command"* of the Consumer device or a new input of data in Object 1016h activates the Supervisor function again.
(*Only if the storage has been carried out previously with Object 1010h.)

17 Heartbeat Producer Protocol

Object 1017h: Producer Heartbeat Time
The Producer heartbeat time defines the heartbeat cycle. If this function is not required, input a 0 time. This function is activated with a time starting from 1 ms. (max. 65535 ms)

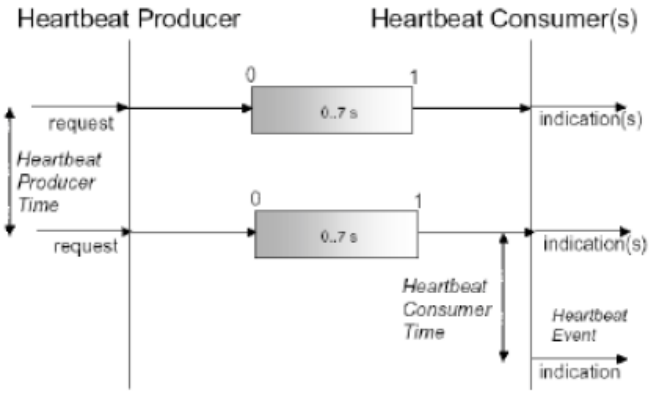
OBJECT DESCRIPTION

INDEX	1017h
Name	Producer Heartbeat Time
Object Code	VAR
Data Type	UNSIGNED16
Category	Conditional; Mandatory if guarding not supported

ENTRY DESCRIPTION

Access	rw
PDO Mapping	No
Value Range	UNSIGNED16
Default Value	0

A "Heartbeat Producer" transfers the message cyclically with the set time. The content of the data byte corresponds to the CAN node status. (Pre-op, Operational, Stopped)



18 CANopen Object Dictionary

Index (hex)	Subindex (hex)	Object	Name	Type	Attr.	M/O

Index: 16-bit address of the record
Subindex: 8-bit pointer to subentries;
used only for complex data structures (e. g. arrays);
if there is no subentry: subindex = 0

Object:	NULL	Entry without data
	DOMAIN	High, variable quantity of data, e. g. program code
	DEFTYPE	Data type definition, e. g. boolean, float, unsigned 16, etc.
	DEFSTRUCT	Definition of an entry, e. g. PDO mapping structure
	VAR	Individual value, e. g. boolean, float, unsigned 16, string, etc.
	ARRAY	Array of data of the same type, e. g. unsigned 16 data
	RECORD	Field of data of different types

Name: Short description of the function
Type: Data type, e. g. boolean, float, unsigned 16, integer, etc.
Attr.: Attribute that defines the access rights to the object:

	rw	Read/write
	ro	Read only
	const	Read only, the value is a constant
M/O	M	Mandatory: the object must be implemented in the device
	O	Optional: the object does not have to be implemented in the device

Structure of the Entire Object Dictionary:

Index (hex)	Object
0000	unused
0001 - 001F	static data types
0020 - 003F	complex data types
0040 - 005F	manufacturer-specific data types
0060 - 0FFF	reserved
1000 - 1FFF	Communication Profile
2000 - 5FFF	Manufacturer-specific Profile
6000 - 9FFF	Standardized Device Profile
A000 - FFFF	reserved

Communication Objects

INDEX (hex)	OBJECT SYMBOL	ATTRIB	Name	M/O	TYPE
1000	VAR	CONST	Device Type	M	Unsigned32
1001	VAR	RO	Error Register	M	Unsigned8
1002	VAR	RO	Manufacturer Status	O	Unsigned32
1003	RECORD	RO	Predefined Error Field	O	Unsigned32
1004	ARRAY	RO	Number of PDO supported	O	Unsigned32
1005	VAR	RW	COB-ID Sync message	O	Unsigned32
1006	VAR	RW	Communication cycle period	O	Unsigned32
1007	VAR	RW	synchr.window length	O	Unsigned32
1008	VAR	CONST	Manufacturer Device Name	O	Visible string
1009	VAR	CONST	Manufacturer Hardware Version	O	Visible string
100A	VAR	CONST	Hardware Version	O	Visible string
100B	VAR	RO	Node-ID	O	Unsigned32
100C	VAR	RW	Guard Time	O	Unsigned32
100D	VAR	RW	LifeTime Factor	O	Unsigned32
1010	VAR	RW	Store parameters (Device Profile)	O	Unsigned32
1011	VAR	RW	Restore parameters (Device Profile)	O	Unsigned32
1014	VAR	RO	COB_ID Emcy	O	Unsigned32
1015	VAR	RW	Inhibit Time Emcy	O	Unsigned32
1016	ARRAY	RW	Consumer Hearbeat time	O	Unsigned32
1017	VAR	RW	Producer Heartbeat time	O	Unsigned16
1018	RECORD	RO	Identity Object	M	PDOComPar
1029	ARRAY	RW	Error Behavior	O	Unsigned8
1800	RECORD		1st transmit PDO Comm. Par.	O	PDOComPar
1801	RECORD		2nd transmit PDO Comm. Par.	O	PDOComPar
1802	RECORD		3rd transmit PDO Comm. Par.	O	PDOComPar
1803	RECORD		4th transmit PDO Comm. Par.	O	PDOComPar
1A00	ARRAY		1st transmit PDO Mapping Par.	O	PDOMapping
1A01	ARRAY		2nd transmit PDO Mapping Par.	O	PDOMapping
1A02	ARRAY		3rd transmit PDO Mapping Par.	O	PDOMapping
1A03	ARRAY		4th transmit PDO Mapping Par.	O	PDOMapping

Manufacturer specific Objects

2100	VAR	RW	Baud Rate	O	Unsigned 8
2101	VAR	RW	Node number	O	Unsigned 8
2102	VAR	RW	CAN Bus Termination	O	Unsigned 8
2103	VAR	RO	Firmware Flash Version	O	Unsigned16
2105	VAR	RW	Save All Bus Parameters	O	Unsigned32
2125	VAR	RO	Battery voltage	O	Unsigned16
2140	Array	RW	Customer Memory	O	Unsigned32
2160	VAR	RO	Raw position data	O	Unsigned32
2161	VAR	RO	Complemented position data	O	Unsigned32
2162	VAR	RO	Raw positon data CRC16	O	Unsigned16

CANopen Encoder Device Profile DS 406 V3.2

Device-specific Objects

INDEX (hex)	Object Symb.	ATTRIB	Name	M/O C2	TYPE
6000	VAR	RW	Operating parameters	M	Unsigned16
6001	VAR	RW	Measuring Units p.Revolution (MUR)	M	Unsigned32
6002	VAR	RW	Total Measuring Range (TMR)	M	Unsigned32
6003	VAR	RW	Preset value	M	Unsigned32
6004	VAR	RO	Position value	M	Unsigned32
6030	ARRAY	RO	Speed Value	O	Unsigned16
6031	ARRAY	RW	Speed Calculation Parameter	M	Unsigned16
6040	ARRAY	RO	Acceleration Value	O	Signed16
6200	VAR	RW	Cyclic Timer	M	Unsigned16
6400	ARRAY	RO	Working Area state	O	Unsigned 8
6401	ARRAY	RW	Working Area Low Limit	O	Unsigned32
6402	ARRAY	RW	Working Area High Limit	O	Unsigned32
6500	VAR	RO	Operating Status	M	Unsigned16
6501	VAR	RO	Measuring Step (Singleturn)	M	Unsigned32
6502	VAR	RO	Number of revolutions	M	Unsigned16
6503	VAR	RO	Alarms	M	Unsigned16
6504	VAR	RO	Supported alarms	M	Unsigned16
6505	VAR	RO	Warnings	M	Unsigned16
6506	VAR	RO	Supported warnings	M	Unsigned16
6507	VAR	RO	Profile and SW version	M	Unsigned32
6508	VAR	RO	Operating time	M	Unsigned32
6509	VAR	RO	Offset value (calculated)	M	Signed32
650A	VAR	RO	Module Identification	M	Signed32
650B	VAR	RO	Serial Number	M	Unsigned32
650D	VAR	RO	Absolute Accuracy	M	Unsigned8
650E	VAR	RO	Device Capability	M	Unsigned8

VAR	= Variable	**const**	= Constants
ARRAY	= Variable Array	**Name**	= Object Name
RW	= Read/Write	**M/O**	= Mandatory or Optional
RO	= Read only	**MAP**	= Object mappable

20 Universal Scaling Function (USF)

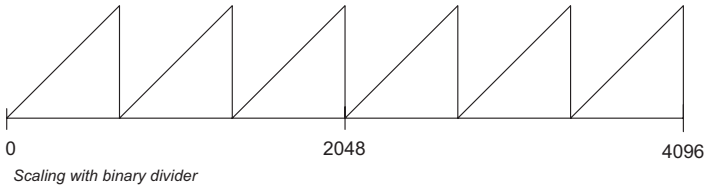
Range end problems with encoders with limited multiturn value

An error appears at the end of the physical resolution of an encoder, when scaling is enabled, if the division of the physical boundaries (GP_U) by the programmable total resolution (TMR) is not an integer.

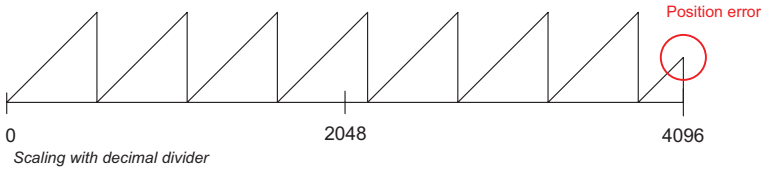
k = GP_U / TMR k <> integer

At the end of the multi-turn range during clockwise rotation, the encoder outputs position zero again. The same error appears immediately, if the encoder is set back to zero with a preset and the maximum multiturn value is approached after.

Example multiturn value 4096



Scaling with binary divider



Scaling with decimal divider

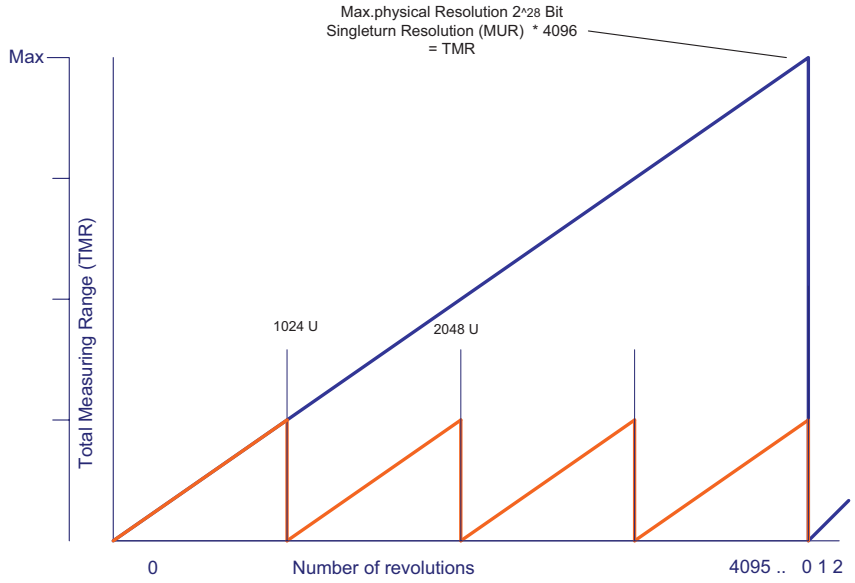
Example with binary divider: Entry Object 6001h MUR = 16384

Total position Scaled = (# of Rotations) * MUR)

Total position $_{Scaled}$ = ((GP_U / STA_U) * 16384)
Total position $_{Scaled}$ = (4096 * 16384)
TMR = 67,108,864

k = GP_U/ TMR k= integer
k = 2^{28} /67,108,864 = 4 -> no position error with multiturn carry-over

Example with binary divider:



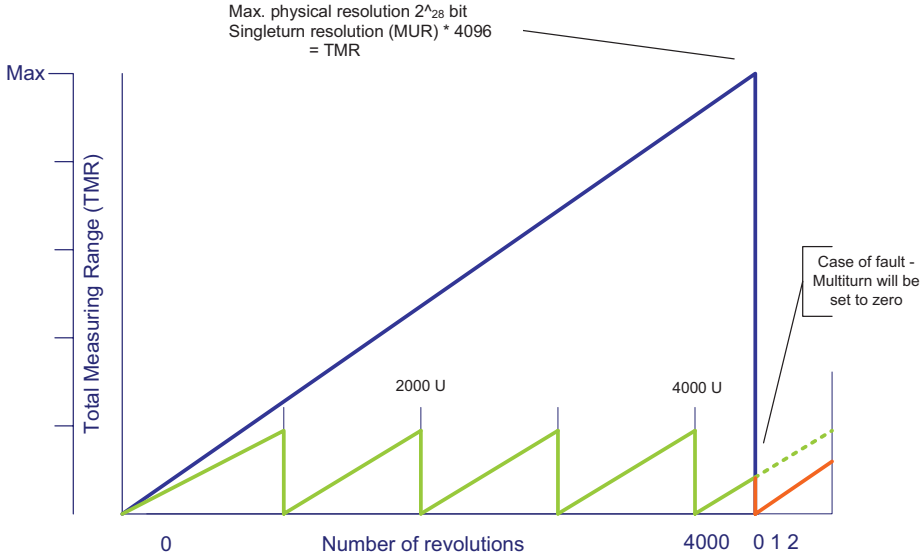
Example with decimal divider:

Entry Object 6001h MUR= 65000
Entry Object 6002h TMR= 65,000,000

Calculated number of MT rotations = 1000

k = GP_U/ TMR k= integer

Error $k = 2^{28} / 65{,}000{,}000 = 4.1297$



21 Solution with USF

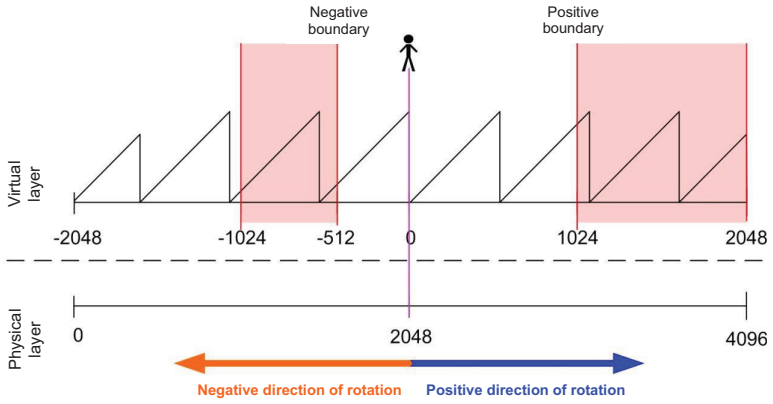
In order to have a "safe" area with sufficient reserve both in the positive and in the negative direction of rotation of the absolute position area of an encoder, the zero point of the sensor must be offset. First, the physical position of the sensor is separated from the position that is sent via CANbus. This creates two layers called physical and virtual layer.

Physical layer
On this level, the absolute raw position data of the mounted sensor is read and used internally as the basis for the calculation of the virtual position.

Virtual layer
The virtual level contains the corrected position data of the encoder. This position data is forwarded with the current MUR/ TMR settings via the bus. The correction positions the zero point of the encoder in the center of the actual measuring range, which avoids the critical areas at the ends. This allows correcting the position error in case of negative direction of rotation of the shaft. After the zero point offset, the boundaries of the critical areas must be defined, so as to allow detecting whether the position is already close to a faulty position overflow.

In order to achieve a good compromise between safety and flexibility, the boundary for the positive critical area has been set to 1/4 of the whole unscaled multiturn resolution (MTA_U).
A step width must be defined in order to avoid simultaneously a fault in case of a negative direction of rotation. This step width represents the distance at which the position ramps of the scaled encoder position repeat themselves. This step width must be smaller than the positive boundary.

It follows from the calculated step width that the negative boundary must be closer to the zero point than the positive boundary. The boundary must be set to 1/8 MTA_U in order to make sure that the boundary is detected before reaching the end of the negative critical area.



If, during the operation of the system, one of these critical areas is reached, a correction must take place, which will shift the current position on the virtual layer so that the physical position is located again outside of the critical area. This will create a virtual position on the user layer, and the encoder will always be in the safe area.

22 Basic Activation of USF

Proceed as follows in order to activate the USF in the encoder:

1. Entry of the gear factor

Object 6001h: Measuring units per revolution (MUR) (resolution)
Object 6002h: Total measuring range (TMR)

Note:
If the ratio TMR/MUR < MTA/4 is not observed, this may also result in a miscalculation and the functionality of the USF cannot be guaranteed.
False entry and range excess are rejected in both objects 6001h and 6002h.

2. Activation of the function with bit 12 Object 6000h Operating Parameters

12	Universal Scaling Function	Disabled	Enabled	o	o

Example: Value in 6000h 0x1004 Scaling active, USF active

3. New encoder referencing the Preset function

Object 6003h: Preset value entry
Value range: 1....max. physical resolution (268435456) 28 bits
Default setting: 0

Note:
When entering the preset value, the system checks automatically whether the point is located within the activated scaling of the total measuring range, otherwise the entry is rejected.

4. USF is active and can be used

23 Error Messages during USF operation

Emergency Objects arise in case of error situations within a CAN network and are triggered depending on the event and transmitted over the bus with a high priority.

Important:
An Emergency Object is only triggered once per "Event". No new object is generated as long as the error is active. Once the error is eliminated, a new Emergency Object with the content 0 (Error Reset or No Error) is generated and transmitted over the bus.
If an error is detected within the USF calculation, the encoder generates an error message with the code 6200h User Software and the yellow DIAG LED flashes.

1. The yellow/red LED flashes cyclically after Power On.

The saved offset value cannot be verified any more, and the device requires a Preset operation.
An Emergency Message 6200 User Software is triggered if a Preset operation is made and the new offset is stored.

2. The green and yellow LEDs blink alternately after Power On or during operation.

The data storage of the offset value cannot be guaranteed. The FRAM did not pass the memory test.
An Emergency Message 5100 Hardware error is triggered. The device should be sent for servicing.

24 Encoder Profile DS 406

Object 6000h Operating Parameters

Bit 0: Code sequence: 0 = increasing for clockwise rotation (cw)
1 = increasing for counter-clockwise rotation (cw)
Bit 2: Scaling function: 0 = disable, 1 = enable; (see Object 6001,6002)
Bit12: USF: 0 = turned off, 1 = activated
Bit13: Speed Format: 0 = revolutions/min, 1 = units/second
Bit14: Startup Mode: 0 = Boot-up after Pre-operational, 1 = Boot-up after operational
Bit15: Event Mode: 0 = position output acc. to TPDO 1800h, 1 = every change in position is output

Defaults: 0x00 (cw,scaling off,USF off,rpm,normal bootup)

Bit	Function	Bit = 0	Bit = 1	C1	C2
0	Code sequence	CW	CCW	m*	m*
1	Commissioning Diagnostic Control	Disabled	Enabled	o	o
2	Activate scaling	Disabled	Enabled	o	m
3	Measuring direction	Forward	Reward	o**	o**
4..11	Reserved for further use				
12	Universal Scaling Function	Disabled	Enabled	o	o
13	Speed Format	RPM	Units/sec	o	o
14	Start-up automatic in OP-Mode	Disabled	Enabled	o	o
15	Event Mode Position	Disabled	Enabled	o	o

*m = function has to be supported **o = optional

Object 6001h: Measuring units per revolution (MUR) (resolution)

This parameter adjusts the desired resolution per revolution. The encoder internally calculates the corresponding scaling factor. The calculated scaling factor MURF (which multiplies the physical position value), is calculated by using the following formula:
MURF = Measuring units per revolution (6001h) / phys. resolution singleturn (6501h)

Byte 0	Byte 1	Byte 2	Byte 3
2^7... 2^0	2^{15}...2^8	2^{23}...2^{16}	2^{31}...2^{24}

value range: 1....max. physical resolution (65536) 16 bits

Note:
It may happen that the TMR and MUR values have been set in such a way, with de-activated USF, that the TMR/MUR ratio does not lie below the prescribed limit of MTA_U/4. An attempt to start USF in these conditions will lead to the detection of this wrong ratio, an error message will then be generated and the option will not be activated.

Object 6002h: Total Measuring Range (TMR)
This parameter adjusts the total measurement range of singleturn and multiturn. The maximum physical resolution affected with a factor. The factor is always < 1. After the scaled overall position of measurement units, the encoder resets to zero (with limitations).

Data content:

Byte 0	Byte 1	Byte 2	Byte 3
2^7... 2^0	2^{15}...2^8	2^{23}...2^{16}	2^{31}...2^{24}

Value range: 1....max. physical resolution 32 bits

Note:
If TMR/MUR is altered, the ratio between TMR and MUR is also checked. An attempt to set a value for TMR that would result in an invalid ratio will trigger an error message and the new value will be dismissed. The old value will remain in the encoder.

Note:
An attempt to activate USF without active scaling will be detected and an error message will be output. The USF Option will not be activated.

Object 6003h: Preset value
The position value of the encoder is set to the entered preset value.
This will allow e. g. to align the zero position of the encoder with the machine zero point.

Data content:

Byte 0	Byte 1	Byte 2	Byte 3
2^7... 2^0	2^{15}...2^8	2^{23}...2^{16}	2^{31}...2^{24}

Value range: 1....max. physical resolution 32 bits
Default setting: 0

When entering the preset value, the system checks automatically assessed whether the point lies within the activated scaling or total measurement range. If this is not the case, the entry is rejected.

Object 6004h: Position value
The encoder outputs the current position value (possibly calculated with a scaling factor).

Data content:

Byte 0	Byte 1	Byte 2	Byte 3
2^7... 2^0	2^{15}...2^8	2^{23}...2^{16}	2^{31}...2^{24}

Value range: 1....max. physical resolution 32 bits
Default setting: current position

Current position output = ((GP_U / STA_U) * MUR) % TMR (Modulo Division)

Object 6030h: Speed value

The encoder outputs the current calculated speed (possibly with a scaling factor) as a 16-bit value. The speed depends on the settings of Object 6031h. These values affect the calculation and the result.

Data content:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

Value range: 0....+/- maximum speed 15000 RPM (signed value)

Note:
For values larger than 12,000 RPM for multiturn, a warning message is generated and the warning bit "Speed exceeded bit 0" is set in Object Warnings 6505h.

Note:
For values larger than 4000 RPM for singleturn, a warning message is generated and the warning bit "Speed exceeded bit 0" is set in Object Warnings 6505h. In addition, the output value is limited to 4,000 RPM.

Note:
The parameters also affecting this object are mentioned in Object 6031h.

Object 6040h: Acceleration value

The encoder outputs the current calculated acceleration (signed) as a 16-bit value. The acceleration is calculated from the speed changes and thus also depends indirectly on the settings of Object 6031h. These values affect the calculation and the result.

Data content:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

Value range: 0.... +/- maximum acceleration

Note:
Negative values mean a negative acceleration (the speed decreases)

An average acceleration a is the change in time of speed v and can thus be described formally from the derivative of speed versus time t, this calculation results in an average acceleration from the difference between speeds Δv at 2 different moments Δt (t2-t1).

a = Δv /Δt or a = v2- v1 / t2-t1

Object 6200h: Cycle timer
Defines the cycle time with which the current position is output using PDO 1 (see Object 1800h). The timer-controlled output becomes active as soon as a cycle time >0 is entered.

Note:
This Object is only present for reasons of compatibility with earlier profile versions. Instead of this Object, please use the Event Timer Subindex (05h) in the current Transmit PDO.

Data content:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

Value range: 0 ... FFFFh (65535) gives a cycle time in milliseconds
Standard value = 0h

Object 6500h: Display Operating Status
This Object displays the status of the programmed settings of Object 6000h.

Data content:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

Data content: see Object 6000h

Object 6502h: Number of Multiturn revolutions
This Object shows the current number of revolutions. The value depends on the encoder type and any value between 4096 (12 bits) and 65535 (16 bits) could occur. This value only affects the number of revolutions. It does not affect the resolution.

Data content:

Byte 0	Byte 1
00	10h

Value range: 1 …65535
Default setting corresponds to 65536 for MT 1 for ST

Object 6503h: Alarms
In addition to the errors that are signalled via emergency messages, Object 6503h provides for further error messages. The corresponding error bit is set to 1 for as long as the error condition applies.

Data content:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

Bit no.	Description	Value = 0	Value = 1
Bit 0	Position error	Position value valid	Position error
Bit 1	Hardware check	No error	Error
Bit 2..15	Not used		

In both cases, if an alarm occurs, an emergency message (ID=80h+node number) is sent together with the error code 1000h (Generic error).

Object 6504h: Supported Alarms
This Object is used to display which alarm messages are supported by the encoder (see Object 6503h).
Data content:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

Range of values: see Object 6503h
The alarm message is supported when the bit is set to 1.
Example:
Bit 0 = 1 Position error display is supported

Object 6505h: Warnings
Warning messages show that tolerances of internal encoder parameters have been exceeded. With a warning message – unlike with an alarm message or emergency message – the measured value can still be valid. The corresponding error bit is set to 1 for as long as the tolerance is exceeded or the warning applies.

Data content:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

Bit no.	Description	Value = 0	Value = 1
Bit 0	Overspeed	none	exceeded Limits: 4000 rpm ST Limits: 12000 rpm MT
Bit 1	not used		
Bit 2	Watchdog Status	System OK	Reset carried out
Bit 3	Operating time	Below < 100000h	> 100000h
Bit 4	Battery warning	Battery > 2.4 VDC	Battery < 2.4 VDC*
Bit 15	Temperature error	Temperature OK	Overtemperature

When Bit 0 is active, an emergency message (ID=80h+node number) is sent together with Error code 4200h (Device specific).
*When Bit 4,15 is active, an emergency message (ID=80h+node number) is sent together with Error code 5200h (Device Hardware).

Object 6506h: Supported Warnings
This Object is used to display which warning messages are supported by the encoder (see Object 6505h).
Data content:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

Range of values: see Object 6505h
The warning is supported when the bit is set to 1.

Object 6400h: Working Area State Register 2 values
This Object contains the current state of the encoder position with respect to the programmed limits. The flags are either set or reset depending on the position of both limit values. The comparison with both limit values takes place in "real time" and can be used for real-time positioning or for limit switching.

Name	Bit	Value	Definition
out of range	0	0_b	Position between minimum and maximum value (refers to module identification, object $650A_h$)
		1_b	Position (refers to minimum and maximum value in module identification, object $650A_h$) is reached or exceeded
range overflow	1	0_b	No range overflow
		1_b	Position is higher than the position value set in work area high limit (object 6402_h)
range underflow	2	0_b	No range underflow
		1_b	Position is lower than the position value set in work area low limit (object 6401_h)

Range of values 8 bits
Data content see bits 0...7

Note:
The Bitposition for the second limit value (6401h,6402h) is starting at Bit 3,4, and 5.

Object 6401h: Working Area Low Limit 2 values
Object 6402h: Working Area High Limit 2 values

These two parameters configure the working area. The state inside and outside this area can be signalled by means of Flag bytes (Object 6400h Working Area State). These area markers can also be used as software limit switches.

Data content:

Byte 0	Byte 1	Byte 2	Byte 3
2^7... 2^0	2^{15}...2^8	2^{23}...2^{16}	2^{31}...2^{24}

Value range: 1....max. physical resolution (2^{32}) 32 bits
Default setting: 33554432 (25 bits) Working Area High Limit for MT 65565 for ST
0 Working Area Low Limit

Object 2100h: Baud rate
This Object is used to change the baud rate via software. The default setting is FFh, which means that the hardware setting for the baud rate has priority. If the value is set between 1..9 and the parameter saved with Object 2105h Save All Bus Parameters, then on the next Power ON or with a reset node, the device will boot up with the modified baud rate.

Data content:

Byte 0
2^7... 2^0

Value range 1 ...8 (see Baud rate table)
Default setting: 0x05h 250 Kbit/s

Important:
The acceptance of a new node number only becomes effective when the encoder is rebooted (Reset/Power-on) or by means of an NMT-Reset Node command. All other settings within the Object table remain unchanged.

Object 2101h: Node address
This Object is used to change the node address via software. The default setting is 0xFFh, which means that the hardware setting for the node address has priority. If the value is set between 1..127 and the parameter saved with Object 2105h Save All Bus Parameters, then on the next Power ON or with a reset node, the device will boot up with the modified node address.

Data content:

Byte 0
2^7... 2^0

Value range 1 ...127 or 1..7Fh
Default setting: 0x3Fh Address 63

Node number 0 is reserved and may not be used by any node.
The resulting node numbers lie in the range 1...7Fh hexadecimal or (1...127)

Important:
The acceptance of a new node number only becomes effective when the encoder is rebooted (Reset/Power-on) or by means of an NMT-Reset Node command. All other settings within the Object table remain unchanged.

Object 2102h: CAN bus termination OFF/ON
This Object is used to set the bus termination via software. The default setting is 1.

Data content:

Byte 0
2^7... 2^0

Value range 0..1
Default setting: 1 *for devices with cable outlet and CAN connection = 1

Object 2103h: Firmware Flash version
This object is used to display the current firmware version as a 16-bit hexadecimal value.
This value serves to verify that the device is to the latest revision.

Data content:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

Value range up to FFFFh
Example: 4FA6h current firmware

Object 2105h: Save All Bus Parameters
This parameter stores the desired bus parameters (Object 2100h, 2101h, 2102h) permanently in the Flash memory. This object is an additional protection against unintentional baud rate or node address modifications.
Only the targeted storage using parameter "save" (hexadecimal 0x65766173) saves the bus parameters baud rate, node address and termination permanently.

Data content:

Byte 0	Byte 1	Byte 2	Byte 3
2^7... 2^0	2^{15}...2^8	2^{23}...2^{16}	2^{31}...2^{24}

Value range: „save" in hexadecimal 0x65766173

Object 2110h: Sensor Configuration Data
This Object is used to get information about the current configuration of the sensor.
The array is displayed as a byte-hexadecimal value.

Byte 0	Byte 1	Byte 2
2^7... 2^0	2^{15}...2^8	2^{23}...2^{16}

Value range up to FF, FFh…….
Can only be used for service purposes.

Object 2120,4h: Actual temperature Position-Sensor *
This Object is used to display the current temperature inside the sensor as a 16-bit hexadecimal value. This value allows determining the momentary device temperature.

Byte 0
2^7... 2^0

Value range up to 00…FFh
Example: 0x59 means about 25°C

The following temperature values can be used as reference values:

-20°C means 0x2Ch
0°C means 0x40h
100°C means 0xA4h

Example: Read value 0x71h from Object 2120,4h
0x71h – 0x40h = 0x31h corresponds to 49°C decimal

Note:
* The temperature value can be mapped as an 8-bit value in the process data, where it will be updated all 60 seconds. Accuracy is ± 6°C, the measurement takes place within the encoder electronics.

Object 2120,2h: Actual temperature lower limit Position-Sensor
Object 2120,3h: Actual temperature upper limit Position-Sensor

This object is used to display the upper/lower temperature limit as a 8-bit hexadecimal value. This value is used to determine the triggering threshold for the Emergency message.

Byte 0
2^7... 2^0

Value range up to 00…FFh
Example: 0x20 means about -32°C

The following temperature values can be used as reference values:

-20°C means 0x2Ch
0°C means 0x40h
100°C means 0xA4h

If this temperature threshold is exceeded in either direction, an Emergency message is output (see below) and a corresponding reaction is triggered.

value range: 0x20h .. 0xACh
Default setting: 0xA2h Temperature High Limit
0x20h Temperature Low Limit

Object 2125h: Battery Voltage (Multiturn only)
This object is used to display the current battery voltage as a 16-bit hexadecimal value.
This value is used to check the integrated battery and shows directly the exact voltage in VDC.

Data content:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

Value range up to 0 ..500
Example: 361 current battery voltage is 3.61 VDC

Limit: corresponds to 2.4 V
Error: 0x3FF no battery or battery discharged

The current battery voltage is 3.62 V.

Object 2140h: Customer Memory (16 Bytes)
These 4 parameters constitute a memory area for the user. 4 data words with a maximum of 4 bytes can be stored. This area is not checked for content, which means that any format may be stored.

Byte 0	Byte 1	Byte 2	Byte 3
2^7... 2^0	2^{15}...2^8	2^{23}...2^{16}	2^{31}...2^{24}

Value range: Numeric, alphanumeric
Default setting: 0

Object 2160h: RAW position value data
In addition, the position data can be output as raw data. The data is transmitted as 32-bit value, logically correct and complemented, a CRC for the position data can also be added to the mapping. Object 1803h may be used to that purpose. The encoder outputs the current original position value directly from the sensor.

Data content:

Byte 0	Byte 1	Byte 2	Byte 3
2^7... 2^0	2^{15}...2^8	2^{23}...2^{16}	2^{31}...2^{24}

Value range: 1....maximum physical resolution (2^{32}) 32 bits for MT (2^{16}) ST

Object 2161h: Complemented RAW position value data
The encoder outputs the complemented current original position value.

Data content:

Byte 0	Byte 1	Byte 2	Byte 3
2^7... 2^0	2^{15}...2^8	2^{23}...2^{16}	2^{31}...2^{24}

Value range: 1....maximum physical resolution (2^{32}) 32 bits for MT (2^{16}) ST

Example for the transmission of RAW and complemented position data:

Message	Byte 0	Byte 1	Byte 2	Byte 3	
2160h	15	3A	7F	01	Raw position data
2161h	EA	C5	80	FE	Complemented raw data
XOR	FF	FF	FF	FF	Result of the check

When an "exclusive OR" function is applied to both position data values, the result must always be a logical "1".
If transmission errors occur for any reason, this can be detected immediately by obtaining a logical "0" after this check.

Object 2162h: Raw position data CRC16
Current Object 2160h Position raw data generates a standard CRC16. CRC-CCITT (CRC-16) $x^{16} + x^{12} + x^5 + 1$ (Polynomial 0x1021)
The implementation performs a polynomial division when the start value used is 0000... This corresponds to a polynomial division if the first n bits of the data flow are complemented. A start value different from 0000... should be preferred, since otherwise missing bits within leading zeros would not be detected in the data flow (just like in a usual division, the leading zeros are not taken into consideration for a polynomial division).

Start value (seed value) used here = 0xFFFF
The polynomial is displayed as a 16-bit hexadecimal value.
This value serves to verify the current raw position date of the device.

Data content:

Byte 0
2^7... 2^0

Value range up to FFFFh
Example: 4FA6h current CRC16 for the position data

Object 1029h Error Behavior
If a serious error is detected, the device should automatically switch to Pre-Operational mode. The settings in this Object can be used to determine how the device is to behave when an error arises. The following error classes are covered:

1029h,Subindex 1 Communication Errors
- Bus Off state of the CAN interface
- Life guarding event has occurred
- Heartbeat monitoring has failed

1029h,Subindex 2 Device Profile Specific
- Sensor error and Controller error
- Temperature error

1029h,Subindex 3 Manufacturer Specific
- Internal error

The value of the Object classes is put together as follows:

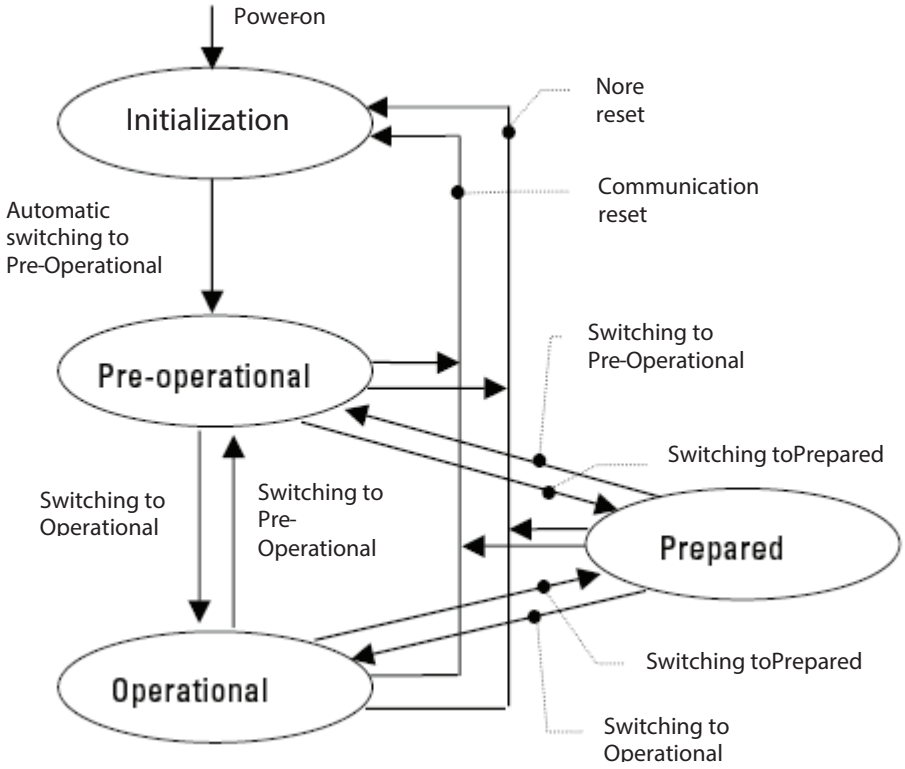
Byte 0
$2^7 ... 2^0$

Value range 8 bits
- 0 Pre-Operational Mode (only if Operational Mode was active before)
- 1 No mode change
- 2 Stopped mode
- 3 .. 127 reserved

Objects not mentioned
All Objects not mentioned here serve as additional information and can be found in Encoder profile DS 406 V3.2.

25 Network Management

The encoder supports the simplified Network Management as defined in the profile for "minimum capability devices" (minimum boot up).
The following function state diagram acc. to DS 301 shows the various node states and the corresponding network commands (controlled by the Network Master via NMT services):



Initialization: This is the initial state after the power supply is applied, following a device Reset or Power ON. The node automatically enters the Pre-operational state once it has run through the Reset and Initialization routines. The LEDs display the momentary status.

Pre-operational: The CAN node can now be addressed via SDO messages or with NMT commands under the standard identifier. Then follows the programming of the encoder or communication parameters.

Operational: The node is active Process values are transmitted through the PDOs. All NMT commands can be evaluated.

Prepared or Stopped: In this state the node is no longer active, which means that neither SDO nor PDO communications are possible. The node can be set to either the Operational or Pre-operational state by means of NMT commands.

26 NMT Commands

All NMT commands are transferred as an unconfirmed NMT Object. Because of the broadcast (network-wide) communication model, the NMT commands are recognized by each station.
A NMT Object is structured as follows:

Byte 0	Byte 1
2^7... 2^0	2^{15}...2^8

COB ID = 0
Byte 0 = Command byte
Byte 1 = Node number

Note:
The COB ID of the NMT Object is always 0 The node is addressed via the node numbers. With node number 0 all nodes are addressed.

Command Byte (Hex)	Description
01h	Start_Remote_Node: Change to Operational
02h	Stop_Remote_Node: Change to Non-Operational
80h	Enter_Pre-Operational_State: Change to Pre-Operational
81h	Reset_Node: Reset Node[1]
82h	Reset_Communication: Reset Communication[2]

[1] All the parameters in the whole Object Dictionary will have their values set to Power-On values.
[2] Only the parameters in the section Communication Profile of the Object Dictionary will have their values set to Power-On values.

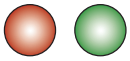
27 LED Displays During Operation

green LED = BUS Status
red LED = ERR Display

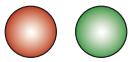
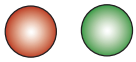
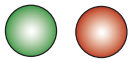
Display	LED	Meaning	Cause of error	Addition
Bus off		No connection to master [2]	Data line interrupted Wrong baud rate Swapped data line	Watch out for combination with ERR LED. If ERR-LED is also turned off, check power supply [3]
Bus Flashing about 250 ms		Connection to master Pre-operational status		SDO communication
Bus Flashing about 1 sec.		Connection to master Stopped status		SDO communication not possible Only NMT commands
Bus on		Connection to master Operational status		PDO transfer is active
ERR off		Device runs error-free		Watch out for combination with BUS LED
ERR Flashing		Connection to master interrupted	Combination with bus-status	BUS LED flashes green or is on, depending on Object 1029h error behavior
ERR on		BUS OFF status	Bus short circuit or wrong baud rate	

The individual LED messages can also appear in combination
[2] Master can be PLC or 2nd communication partner
[3] Operating voltage

LED combinations during operation

Display	LED	Meaning	Cause of error	Addition
ERR Flashing		Red LED flashing Red LED flashes briefly, duration 3 sec.	Temperature overflow Sensor monitoring Single step error Sensor LED current monitoring	Device on CAN bus Connection to master OK + additional cause of error

Error display upon switching on

Display	LED	Meaning	Cause of error	Addition
ERR + BUS Flashing		Alternating quick flashing of green and red LED	Data connection to sensor is faulty. Sensor is defective	Device needs to be sent to manufacturer for service
ERR + BUS Flashing		Alternating quick flashing of green and red LED (300 ms)	Watchdog error	Device needs to be sent to manufacturer for service
ERR Flashing		Connection to master interrupted		No CAN Bus available
Bus +Err flashing fast		LSS Layer Service active. Global mode activated	Encoder waiting for configuration	LSS mode

28 Abbreviations Used

CAL CAN Application Layer. Application layer (layer 7) in the CAN Communication Model
CAN Controller Area Network
CiA CAN in Automation. International Association of Users and Manufacturers of CAN products
CMS CAN Message Specification. Service element of CAL
COB Communication Object. Transport unit in the CAN network (CAN message). Data will be sent over the network within a COB.
COB-ID COB-Identifier. Unique identifier of a CAN message. The identifier defines the priority of the COB in the network.
DBT Distributor. Service element of CAL, responsible for the dynamic allocation of identifiers.
DS Draft Standard
DSP Draft Standard Proposal
ID Identifier, see COB-ID
LMT Layer Management. Service element of CAL, responsible for the configuration of the parameters in the individual layers of the communication model.
LSB Least significant bit/byte
MSB Most significant bit/byte
MT Multiturn encoder
NMT Network Management. Service element of CAL, responsible for the initialization, configuration and error handling in the network.
OSI Open Systems Interconnection. Layer model for describing the function areas in a data communication system.
PDO Process Data Object. Object for the exchange of process data.
RTR Remote Transmission Request; Data request telegram.
SDO Service Data Object. Communication Object, by means of which the Master can access the Object Dictionary of a node.
ST Singleturn encoder
SYNC Synchronization telegram. Stations on the Bus reply to the SYNC command by transmitting their process value.

29 Decimal-Hexadecimal Conversion Table

In case of numbers, decimal values are indicated as figures without extension (e. g. 1408), binary values are followed by b (e. g.1101b) and hexadecimal values are followed by h (e. g. 680h) behind the figures.

Dec	**Hex**	Dec	**Hex**	Dec	**Hex**	Dec	**Hex**
0	**00**	32	**20**	64	**40**	96	**60**
1	**01**	33	**21**	65	**41**	97	**61**
2	**02**	34	**22**	66	**42**	98	**62**
3	**03**	35	**23**	67	**43**	99	**63**
4	**04**	36	**24**	68	**44**	10	**64**
5	**05**	37	**25**	69	**45**	101	**65**
6	**06**	38	**26**	70	**46**	102	**66**
7	**07**	39	**27**	71	**47**	103	**67**
8	**08**	40	**28**	72	**48**	104	**68**
9	**09**	41	**29**	73	**49**	105	**69**
10	**0A**	42	**2A**	74	**4A**	106	**6A**
11	**0B**	43	**2B**	75	**4B**	107	**6B**
12	**0C**	44	**2C**	76	**4C**	108	**6C**
13	**0D**	45	**2D**	77	**4D**	109	**6D**
14	**0E**	46	**2E**	78	**4E**	110	**6E**
15	**0F**	47	**2F**	79	**4F**	111	**6F**
16	**10**	48	**30**	80	**50**	112	**70**
17	**11**	49	**31**	81	**51**	113	**71**
18	**12**	50	**32**	82	**52**	114	**72**
19	**13**	51	**33**	83	**53**	115	**73**
20	**14**	52	**34**	84	**54**	116	**74**
21	**15**	53	**35**	85	**55**	117	**75**
22	**16**	54	**36**	86	**56**	118	**76**
23	**17**	55	**37**	87	**57**	119	**77**
24	**18**	56	**38**	88	**58**	120	**78**
25	**19**	57	**39**	89	**59**	121	**79**
26	**1A**	58	**3A**	90	**5A**	122	**7A**
27	**1B**	59	**3B**	91	**5B**	123	**7B**
28	**1C**	60	**3C**	92	**5C**	124	**7C**
29	**1D**	61	**3D**	93	**5D**	125	**7D**
30	**1E**	62	**3E**	94	**5E**	126	**7E**
31	**1F**	63	**3F**	95	**5F**	127	**7F**

30 Glossary

Baud rate
The baud rate is the data transfer rate. It is linked to the nominal bit timing. The maximum possible baud rate is dependent on numerous factors that affect the transfer time on the bus. There is a significant connection between the maximum baud rate and the bus length and type of cable. In CANopen the various baud rates are defined between 10 Kbit/s and 1 Mbit/s.

CANopen
CANopen is a protocol based on CAN that was originally developed for industrial control systems. The specifications include various device profiles as well as the framework for specific applications. CANopen networks are used in off-road vehicles, electronics on-board ships, medical equipment and the railways. The very flexible application layer together with the many optional features are ideal for customized solutions. Furthermore, a wide variety of configuration tools are available. On this basis the user is able to define device profiles that are specific to his application. More information on CANopen can be found in the Internet at www.can-cia.org.

EDS file
The EDS (Electronic Data Sheet) is provided by the vendor/manufacturer of the CANopen device. It has a standardized format for describing the device. The EDS contains information concerning:

- File description (name, version, creation date, among others)
- General device information (manufacturer's name and code)
- Device name and type, version, LMT address
- Supported baud rates and Boot-up ability
- Description of the supported Objects and their attributes

Node number
Every device within a CANopen network can be identified by its node number (Node-ID). The permitted range for node numbers is from 1 to 127 and each may only occur once within a network.

Network Management
In a distributed system, various tasks arise that have to do with the configuration, initialization and control of stations on the network. This functionality is provided in CANopen by the defined service element »Network Management (NMT)«.

PDO
The Process Data Objects (PDOs) provide the actual transport means for transferring the process data (Application Objects). A PDO is transmitted by a Producer and can be received by one or more Consumers.

PDO Mapping
The size of a PDO can be up to 8 byte. It can be used to transport several Application Objects. PDO Mapping describes the definition of the structure of the Application Objects within the data field of the PDO.

SDO
The confirmed transfer of data, of any length, between two stations on the network occurs via Service Data Objects (SDOs). Data transfer takes place in the Client-Server mode.

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