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9 CANopen

This document reflects the Novotechnik sensor protocol implementation of the standard CANopen protocol.

A basic knowledge of the CAN Bus is required for a proper understanding of this document.

Most of the definitions made are according to the following CiA Standard specifications.

For making use of all the features that these specifications offer, a knowledge about them is absolutely necessary.

The sensor supports the CANopen Communication profile DS-301, V4.02, Encoder profile DSP-406, V3.2 and Layer Setting Services (LSS) DSP-305, V2.1.1

9.1 EDS Files

For integration in a common CANopen projecting tool, electronic data sheet (*.eds) files are provided.

These files can be downloaded from the Novotechnik Web Site, see Downloads/Operating manuals where also this document can be found.

⇒ **Electric data sheet see file TIM_CANopen_Vx.x.eds**

9.2 Features

9.2.1 Basic information

Vendor ID: 386 = 0x0182 (Novotechnik)
Product code: 04028 = 0x0FBC
Rev.-No.: 0x312E3031
Serial No.: see product label, "xxxxxxx" z.B. 14401234

9.2.2 Basics based on CiA DS-301, V4.02

CAN Identifier	Standard 11 bit according to pre-defined connection set:
	<u>Services</u> <u>COB-ID</u>
	NMT 0x00
	SYNC 0x080
	EMCY 0x080 + Node-ID
	PDO1 (Tx) 0x180 + Node-ID
	SDO (Rx) 0x600 + Node-ID
CAN Bit rates	SDO (Tx) 0x580 + Node-ID
	Bit rate is defined in the ordering code:
	6_9: 10 kBaud
	6_8: 20 kBaud
	6_7: 50 kBaud
	6_5: 125 kBaud
	6_4: 250 kBaud
Node-ID	6_3: 500 kBaud
	6_2: 800 kBaud
SYNC	6_1: 1000 kBaud
	setting per LSS (see chapter 9.5 LSS / Layer Setting Service)
Time Stamp	0x7F
	setting per LSS (see chapter 9.5 LSS / Layer Setting Service) or object 0x100B (see chapter 9.6.1 SDO Services)
Emergency Messages	Consumer
Node Guarding	No
Heartbeat	Producer
Non-volatile storage	yes
Program Download	no
NMT Service	Slave

9.2.3 Basics based on CiA DSP-406, V3.2

Encoder class	☒ C1 ☐ C2
Encoder type	Absolute Linear Encoder

9.2.4 Basics SDO communication

SDO communication	1 Server
expedited transfer	yes
segmented transfer	no
Block transfer	no

9.2.5 Basics PDO communication

PDO communication principle	Producer
TPDO	TPDO: asynchronous with Event Timer, synchronous, Remote Transmission Request RTR
PDO Mapping	constant
max. PDO Mapping logs per PDO	2

9.3 Object Library

9.3.1 Communication Profile Area based on DS-301 V4.02

Object description			Entry description			
Index/ subindex	Name	Data Type	Access	PDO Mapping	Default value	Comment
1000	device type	unsigned32	ro	no	0x000A0196	Device profile 406 multi-sensor encoder interface
1001	error register	unsigned8	ro	no	0x00	See chapter 9.8 <i>Error Handling</i> : 0x00: No error 0x81: transducer error
1002	manufacturer status register	unsigned8	ro	no	1	Additional manufacturer spec. status register (see chapter 9.4.1 <i>Object 1002</i>)
1005	COB-ID SYNC	unsigned32	rw	no	0x00000080	COB-ID SYNC message (CAN-identifier)
1008	manufacturer device name	visible_string	const	no	f.e. TIM-0100-306-614-106	Device name, see datasheet/ordering code
1009	Hardware	visible_string	const	no	1.00	Manufacturer Hardware Version
100A	Software	visible_string	const	no	1.00	Manufacturer Software Version
100B	Node-ID	unsigned32	ro	no	127	Node-ID (can be changed via LSS s. chapter 9.5.1 <i>Configuration of Node-ID</i>)
100E	COB ID Error Control	unsigned32	rw	no	0x00000700 + Node-ID	COB ID Error Control
1010	store parameter field	unsigned8	ro	no	1	This entry supports saving of parameters in non volatile memory. With a read access the device provides information about its saving capabilities. For saving the signature "save" (0x65766173) must be written.
1010/1	store parameter	unsigned32	rw	no	0x73617665	Save all parameters
1011	restore default parameters	unsigned8	ro	no	1	This entry supports restoring of default parameters. With a read access the device provides information about its capabilities to restore these values. For restoring the signature "load" (0x6461666c) must be written.
1011/1		unsigned32	rw	no	0x6C6F6164	Restore all default parameters
1014	COB-ID EMCY	unsigned32	rw	no	0x00000080 + Node-ID	COB-ID used for emergency message (Emergency Server).
1017	producer heart-beat time	unsigned16	rw	no	0x00000000 disabled	Heartbeat time periode in .ms. Range 0...65535
1018	identify object	unsigned8	ro	no	4	General information about the device. This information is also used as the LSS address when using "switch mode selective" command
1018/1		unsigned32	ro	no	0x00000182	Vendor ID
1018/2		unsigned32	ro	no	0x0FBC	Product code
1018/3		unsigned32	ro	no	0x312E3031	Revision number
1018/4		unsigned32	ro	no	xxxxxxx	Serial number (see chapter 9.2.1 <i>Basic information</i>)
1200	Server SDO parameter 1	unsigned8	ro	no	2	Number of largest sub-index
1200/1		unsigned32	ro	no	0x00000600 + Node-ID	COB-ID client to server (Rx)
1200/2		unsigned32	ro	no	0x00000580 + Node-ID	COB-ID server to client (Tx)

Object description			Entry description			
Index/ subindex	Name	Data Type	Access	PDO Mapping	Default value	Comment
1800	transmit PDO communication parameter 1	unsigned8	ro	no	5	It contains the communication parameters of the current PDO the device is able to transmit.
1800/1		unsigned32	rw	no	0x00000180 + Node-ID	COB-ID used by PDO1, transmission type of PD01
1800/2		unsigned8	rw	no	0xFE = 254	Transmission type see chapter 9.7.1 <i>PDO Setting</i>
1800/5		unsigned16	rw	no	1	Event timer in ms Range 1...65535
1A00	TPDO mapping parameter 1					Contains the mapping for the PDOs the device is able to transmit
1A00/0		unsigned8	const	no	0x2	Number of entries
1A00/1		unsigned32	const	no	0x60200120	Mapping entry 1: position value
1A00/2		unsigned32	const	no	0x60300110	Mapping entry 2: speed value

9.3.2 Device Profile Area

Object description			Entry description			
Index/ subindex	Name	Data Type	Access	PDO Mapping	Default value	Comment
6000	operating parameter	unsigned16	rw	no	0x0	This object contains the functions for code sequence and commissioning diagnostic control
6005	Linear encoder measuring step settings					Object sets the number of distinguishable steps over the total measuring range (total resolution)
6005/0		Unsigned8	ro	no	0x02	Number of objects
6005/1		unsigned32	ro	no	100000	Position measuring step 0.001 µm
6005/2		unsigned32	ro	no	100	Speed measuring step 0.01mm/s
6010	preset value					This object supports adaption of the encoder zero point to the mechanical zero point of the system
6010/0		unsigned8	ro	no	0x01	Number of available channels
6010/1		integer32	rw	no	0x0	Preset value
6020	position value					This object defines the output position value
6020/0		unsigned8	ro	no	0x1	Number of available channels
6020/1		integer32	ro	yes	no	Position value
6030	speed value					This object defines the output speed value
6030/0		unsigned8	ro	no	0x1	Number of available channels
6030/1		integer16	ro	yes	no	Speed value
6200	cyclic timer	unsigned16	rw	no		Corresponds to event timer (object 1800/5)
6500	operating status	unsigned16	ro	no	0x0	This gives information on encoder internal programmed parameters.
6501	measuring steps	unsigned32	ro	no	1000000	Position measuring step in 0.001 µm

9.4 Explanations to Object Library

9.4.1 Object 0x1002 Manufacture Status Register

Different to DS-301 chapter 2 the data type of the TIM CANopen sensor is "unsigned8" instead of "unsigned32". The definition of the manufacture status register is as follows:

Byte7	Byte6	Byte5	Byte4	Byte3	Byte2	Byte1	Byte0
0	T	E3	E2	E1	E0	S	N

N:	Status	0 = sensor in error state 1 = normal running state (valid position and speed data transmitted)
S:	Start up	0 = normal running state 1 = start up or internal test mode
E0:	Magnet Error	0 = one magnet detected 1 = no or more than one magnet detected
E1:	Range Error	0 = no error 1 = the calculated position is out of range when also the position and speed value is set to zero 1 = the velocity value maybe not correct
E2:	Data flash error	0 = no error 1 = the CRC check of data flash parameter memory failed
E3:	Controller error	0 = no error 1 = the internal test routines detects an error
T:	Temperature μ C	0 = T < Max temperature 1 = T > Max temperature

9.5 LSS / Layer Setting Service

To configure the encoder via the LSS (according CiA DS-305) the encoder is handled as a slave, the PLC must have a LSS master functionality.

A LSS-message is composed as follows:

COB-ID	DLC	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
--------	-----	---------	-------	-------	-------	-------	-------	-------	-------

This applies to the COB-ID:

- LSS-Master $\Rightarrow$ LSS-Slave: 2021 (0x7E5)
- LSS-Slave $\Rightarrow$ LSS-Master: 2020 (0x7E4)

LSS can only be used when the encoder is in the stopped status or pre-operational status.
The NMT command for setting the encoder in stopped status is:

COB-ID	DLC	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
0x7E5	8	0x04	0x00	0x00	0x00	0x00	0x00	0x00	0x00

To program via LSS the sensor has to be switched to LSS configuration state.
There are two possible ways to do so:

- **Switch Mode Selective:**
only the addressed CANopen device is switched to the LSS configuration state

LSS requires data content in the following objects:

Example:			
Vendor-ID	(see index 1018/1)	0x0182	LSS-Command 0x40
Product code	(see index 1018/2)	0x0BE0	LSS-Command 0x41
Rev.No.	(see index 1018/3)	0x10003	LSS-Command 0x42
Serial-No.	(see index 1018/4)	0x12345678	LSS-Command 0x43

After receiving the identification objects, the encoder answers with LSS-Command **0x44**.

COB-ID	DLC	Rx/Tx	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
0x7E5	8	Rx	0x40	0x82	0x01	0x00	0x00	0x00	0x00	0x00
0x7E5	8	Rx	0x41	0xE0	0x0B	0x00	0x00	0x00	0x00	0x00
0x7E5	8	Rx	0x42	0x03	0x00	0x01	0x00	0x00	0x00	0x00
0x75E	8	Rx	0x43	0x78	0x56	0x34	0x12	0x00	0x00	0x00
0x7E4	8	Tx	0x44	0x00	0x00	0x00	0x00	0x00	0x00	0x00

- **Switch Mode Global:** all CANopen devices supporting LSS are switched to the LSS configuration state

COB-ID	DLC	Rx/Tx	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
0x7E5	8	Rx	0x04	0x01	0x00	0x00	0x00	0x00	0x00	0x00

When the CAN devices are in configuration state the Node-ID and/or the baud rate can be changed.

9.5.1 Configuration of Node-ID

When programming the Node-ID only one slave may be connected.

The Node-ID can be programmed with the LSS-Command **0x11**

N ID: new Node-ID in the range of 1...127

Err Code: 0: protocol successfully completed / 1: Node-ID out of range

COB-ID	DLC	Rx/Tx	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
0x7E5	8	Rx	0x11	N ID	0x00	0x00	0x00	0x00	0x00	0x00
0x7E4	8	Tx	0x11	Err Code	0x00	0x00	0x00	0x00	0x00	0x00

Change of Node-ID will cause:

- Automatic alteration of COB-ID's for SDO, EMCY, Heartbeat and TPDO.
- Non-volatile Node-ID storage through „Store Configuration“ in the LSS mode configuration.

9.5.2 Configuration of Bit Rate

The Bit Rate can be programmed with LSS-Command **0x13**

Table Index:
0x09: 10 kBaud
0x08: 20 kBaud
0x06: 50 kBaud
0x04: 125 kBaud
0x03: 250 kBaud
0x02: 500 kBaud
0x01: 800 kBaud
0x00: 1000 kBaud

Err Code: 0: protocol successfully completed 1: Bit timing not supported

COB-ID	DLC	Rx/Tx	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
0x75E	8	Rx	0x13	0x00	Table Index	0x00	0x00	0x00	0x00	0x00
0x74E	8	Tx	0x13	Err Code	0x00	0x00	0x00	0x00	0x00	0x00

The baud rate gets active after receiving the 'Activate Bit timing parameters' command or after the 'Store Configuration Data' command with the next Power on Reset.

9.5.3 Activate Bit timing parameter

With the LSS-Command **0x15** the LSS master shall activate the bit timing defined by the configure bit timing parameters service.

COB-ID	DLC	Rx/Tx	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
0x75E	8	Rx	0x15	Switch delay		0x00	0x00	0x00	0x00	0x00

Switch delay: Time in ms internal multiplied by 2 when the new bit timing parameters become active.

Note:

No communication should be performed until the (2*switch delay) time runs out.

9.5.4 Store Configuration Data

The LSS configuration data (Node-ID and Bit Rate) are stored to the non-volatile memory of the sensor using LSS-Command **0x17**

Err Code: 0: protocol successfully completed 2: storage media access error

COB-ID	DLC	Rx/ Tx	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
0x75E	8	Rx	0x17	0x00	0x00	0x00	0x00	0x00	0x00	0x00
0x74E	8	Tx	0x17	Err Code	0x00	0x00	0x00	0x00	0x00	0x00

9.6 SDO Services

Service Data Objects SDO (according to CiA DS-301) manage the parameter data exchange, e.g. the non-cyclical execution of the preset function.

Parameters of device object library (object index/subindex see chapter 9.3 *Object Library*) can be read, written or stored by means of SDO.

9.6.1 SDO Download

The SDO download service is used to configure the parameters.

Command 0x2_: 0x22 write command, parameter to encoder
0x23 write command, 4 Byte parameter to encoder
0x27 write command, 3 Byte parameter to encoder
0x2B write command, 2 Byte parameter to encoder
0x2F write command, 1 Byte parameter to encoder
Command 0x60: confirmation: parameter received

Index: Object dictionary parameter index
Subindex: Object dictionary parameter subindex

COB-ID	DLC	Rx/ Tx	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
0x600+Node-ID	8	Rx	0x2_	Index		Sub-index	Data LSB	Data	Data	Data MSB
0x580+Node-ID	8	Tx	0x60	Index		Sub-index	0x00	0x00	0x00	0x00

Example: object index 0x1010 subindex 01 "store all parameters"

0x600+Node-ID	8	Rx	0x23	0x10	0x10	0x01	0x73	0x61	0x76	0x65
0x580+Node-ID	8	Tx	0x60	0x10	0x10	0x01	0x00	0x00	0x00	0x00

Example: object index 0x1011 subindex 01 "restore all parameters"

0x600+Node-ID	8	Rx	0x23	0x11	0x10	0x01	0x6C	0x6F	0x61	0x64
0x580+Node-ID	8	Tx	0x60	0x11	0x10	0x01	0x00	0x00	0x00	0x00

Example: object index 0x100B subindex 0 "set new node-ID" with 64

0x600+Node-ID	8	Rx	0x23	0x0B	0x10	0x00	0x80	0x00	0x00	0x00
0x580+Node-ID	8	Tx	0x60	0x0B	0x10	0x00	0x01	0x00	0x00	0x00

NODE-ID

Using writing to object 0x100B, non-volatile storage has to be done by writing the "save"- signature (0x65766173) on object 0x1010/1. These changes will become effective after a communication restart or a power up. Changing the Node-ID will affect all COB-IDs according to the "predefined connection set".

Example: COB-ID TPDO = 0x180 + (Node-ID)

9.6.2 SDO Upload

The SDO upload service is used to read the parameters.

Command 0x40: read command, parameters from encoder
Command 0x4_: 0x42 read command, parameter to encoder

Index: Object dictionary parameter index
Subindex: Object dictionary parameter subindex

COB-ID	DLC	Rx/ Tx	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
0x600+Node-ID	8	Rx	0x40	Index		Sub-index	0x00	0x00	0x00	0x00
0x580+Node-ID	8	Tx	0x42	Index		Sub-index	Data LSB	Data	Data	Data MSB

9.6.3 SDO Abort

If the SDO download or SDO upload service fails for any reason, the sensor responds with a SDO abort protocol.

Abort Code: 0x06090011 subindex does not exist
0x06090030 value exceeded
0x06020000 object does not exist
0x06010001 object is write only
0x06010002 object is read only
0x08000020 data transport error
0x08000000 general error
0x08000022 wrong state

COB-ID	DLC	Rx/ Tx	Command	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
0x580+Node-ID	8	Tx	0x80	Index		Sub-index	Abort code			

9.7 Process Data PDO

Process Data Objects (according CiA DS-301) manage the process data exchange, f.e the cyclical transmission of the position value. The process data exchange with the CANopen PDOs is a very slim process without protocol overhead.

9.7.1 PDO Setting

One Transmit PDO (TPDO) with max. 8 bytes is provided:

0x1800 TPDO1: default: asynchronous with event timer switched on (changeable to synchronous)

Subindex 1: COB-ID PDO. The PDO can also be disabled with this parameter:

Bit number	Value	Meaning
31 (MSB)	0	PDO exists/valid
31 (MSB)	1	PDO does not exist / is not valid
10-0 (LSB)	X	Bits of PDO COB-ID

Subindex 2: The transmission type defines the transmission character of the PDO:

Transmission type	PDO Transmission synchronous	PDO Transmission asynchronous	RTR only
0 ... 240	X		
254; 255		X	
252; 253		X	X
241 - 251	not valid reserved		

Synchronous mode:

When the sensor is in NMT operational state and the transmission type is between 0 ... 240 the synchronous mode is enabled. The PDO is transmitted by the sensor after receiving every nth SYNC object.

The SYNC object has the following format:

COB-ID	DLC	Rx/ Tx	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
0x080*	0	Rx	-	-	-	-	-	-	-	-

* The COB-ID of the SYNC object message can be individually programmed with Index 1005.

So the COB-ID of the SYNC message can be different.

Asynchronous mode:

If the transmission type is set to 254 or 255 the PDO transmission is asynchronous from the SYNC object. The PDO is transmitted after the event timer (index 1800/5) or cyclic timer (index 6200) is expired. Both objects control the same timer.

Event timer meaning:

0: PDO transmission disabled
1...65535: PDO transmission in [ms]

Polling with remote frames

The polling of the PDO data with remote frames is independent from the transmission type (Index 1800/2). The PDO is transmitted by the sensor after receiving the corresponding PDO remote frame.

The PDO remote frame has the following format:

COB-ID	DLC	Rx/ Tx	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
PDO COB-ID + RTR bit	0	Rx	-	-	-	-	-	-	-	-

9.7.2 PDO message format

The PDO message mapping is described in Index 1A00.

COB-ID	DLC	Rx/ Tx	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
0x180 + Node-ID	6	Tx	Position LSB	Position	Position	Position MSB	Speed LSB	Speed MSB-	-	-

For the PDO message the actual measuring steps for the position and speed values can be read with object linear encoder measuring step settings (Index 6005).

9.8 Error Handling

Emergency objects are triggered by the occurrence of a sensor-internal error. An emergency object is transmitted only once per "error event". If one or all errors are repaired, the device transmits an emergency object with the error code 0x000 "reset error / no error". This message contains also error register with the remaining errors.

9.8.1 Emergency Messages

COB-ID EMCY	DLC	Rx/ Tx	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
0x80+Node-ID	8	Tx	Emergency Error Code (see next table)		Error Register Object 0x1001	0x00	0x00	0x00	0x00	0x00

COB-ID EMCY in object 0x1014.

Two Error conditions are defined: 0x50xx Device Hardware Error and 0x63xx Data Set Error

Error-Code Byte 0,1	Error-Register Byte 2	Description
0x0000	0x00	<i>Sensor Error resetted, no Error</i>
0x5000	0x81	<i>Device Hardware Error</i> <u>Cause:</u> The "Device Hardware Error" is send when the microcontroller detects no stop pulses during one measuring cycle and when the Error Counter runs out.
0x6300		<i>Data Set Error</i> <u>Cause:</u> The "Data Set Error" is send by the sensor when the internal test function detects a mismatch between the new calculated and the stored checksum of the non-volatile memory of the sensor. The checksum is checked during the NMT Initialisation state. The checksum is also checked when the LSS Store Configuration Data command 10.1.4 or a valid SDO download to Object 0x1010 (store parameters) is received. This error can only be cleared by a reset of the device and a successful checksum comparison in the new initialization state.
	0x01	Data Set Error
	0x081	Device Hardware Error and Data Set Error

9.9 Error Control Service

Through error control services the NMT detects failures in a CAN-based Network. When the error control service is enabled the TIM CANopen sensor cyclically transmits a heartbeat message. One or more heartbeat consumer receives the indication. The relationship between producer and consumer is configurable via the object dictionary by SDO. By default the heartbeat is disabled. The first byte of the heartbeat message contains the actual network management state of the sensor.

State:

0x00	Bootup
0x04	Stopped
0x05	Operational
0x07F	Pre-operational

Heartbeat protocol:

COB-ID EMCY	DLC	Rx/ Tx	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
0x700+Node-ID	1	Tx	State							

9.10 Non-Volatile Storage and Data Restoration

Default values for all data objects are stored in the non-volatile program memory. Data encryption to the non-volatile memory is only admitted in the pre-operational status.

• Storage via LSS:

Data must be stored through the LSS Service Configuration/Store while in LSS Configuration Mode (see chapter 9.5 *LSS / Layer Setting Service*)

• Storage via SDO:

Object 0x1010:

Data is stored in the non-volatile memory during encryption of object 0x1010 with „save“ signature (0x65766173).

Object 0x1011:

Encryption of object 0x1011 with the signature „load“ (0x6461666C) will upload data from the non-volatile memory.

Default settings are being restored (see chapter 9.6

SDO Services).

9.11 Abbreviations

CAN	Controller Area Network
ch	channel
COB-ID	Communication Object Identifier
const	constant parameter, only readable
DLC	Data Length Code
DS	Draft Standard
EMCY	Emergency Service
NMT	Network-Management
PDO	Process Data Object
Pos	Position (value)
ro	read only, parameter can change
rw	read/write
Rx	Novotechnik sensor is consumer of the CAN data frame
RTR	Remote Transmission Request
SDO	Service Data Object
SYNC	Synchronisation message
TPDO	Transmit Process Data Object
Tx	Novotechnik sensor is producer of the CAN data frame

9.12 Document Changes

Revision	Changes	Date	Who
V_00	• First edition	23.10.14	VM/mm
V_01	•		
V_02	•		
V_03	•		
V_04	•		
V_05	•		