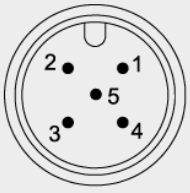
positilt®-PTDM
Inclination Sensors

Output specifications
CANopen and SAE J1939

CANOP CANopen	Communication profile	CANopen CiA 301 V 4.02, Slave
	Encoder profile	CiA 410 V 1.2, Profile „Inclinometer“
	Configuration services	LSS, CiA Draft Standard 305 (Transmission rate, node ID)
	Error Control	Node guarding, Heartbeat, Emergency message
	Node ID	Adjustable via LSS or SDO, default: 127
	PDO	1 TxPDO, 0 RxPDO, no linking, static mapping
	PDO Modes	Event-/Time triggered, Remote-request, Sync cyclic/acyclic
	SDO	1 Server, 0 Client
	Certified	yes
	Transmission rate	50 kBit … 1 Mbit, adjustable via LSS or SDO, default: 125 kBit
	Bus connection	M12 conncector, 5 pin
	Bus with integrated terminating resistance	optional
	Bus, galvanic isolated	no

Specifications	Excitation voltage	8 ... 36 V DC
	Excitation current	15 mA typical at 24 V DC 30 mA typical at 12 V DC 100 mA max.
	Measuring rate	1 kHz (standard)
	Stability (temperature)	±100 x 10^{-6} / °C f.s.
	Repeatability	1 LSB
	Operating temperature	-40 … +85 °C
	Protection	Reverse polarity, short circuit
	EMC	DIN EN 61326-1:2013

Signal wiring
Connector M12, 5 pin



View to the sensor connector

Output signals	Connector pin no.
Shield	1
Excitation +	2
GND	3
CAN-H	4
CAN-L	5

Overview Setup, User Configuration

Setup

Before connecting the sensor to the CAN-Bus the devices have to be checked for correct bitrate and unique node-IDs. Both parameters are configurable by Layer-Setting-Service (LSS) or by Service Data Object (SDO).

After power-on the sensor will enter pre-operational state and send a boot-up message being ready for configuration by Service Data Objects. Parameters configured by the user can be stored nonvolatile by SAVE command. On receiving "NMT-Node-Start" the sensor transits to operational state and starts process data transmission. When "Auto-Start" is configured the sensor will automatically transit to operational after boot-up without a need for the Node-Start message.

Node monitoring is supported by Node Guarding and Heartbeat protocol. Node Guarding implements cyclic querying of the node status by the NMT-Master within the guard time window. The Heartbeat protocol provides automatic transmission of the node status (heartbeat message) by the slave within producer heartbeat time window.

By using the CAN example protocols included in this manual the sensor may be used without CANopen master device.

⚠ WARNING **Risk of injury by unexpected machine movement!**

- Changing parameters may cause unexpected machine movement.
- Changing parameters may influence dependent parameters e.g. changing the resolution may have influence on position of CAM switches.
- Precautions have to be taken to avoid damage to human and machine parts!
- Change parameters only when machine is in a safe condition!

Configuration Message

Service Data Object (SDO)

Configurable parameters of the sensor are accessible by peer to peer communication. The identifier (COB) of the SDO message is defined by the predefined connection set. Parameters to be uploaded or downloaded are addressed by Index and Subindex.

11-Bit CAN-Id	8 Byte data frame							
SDO COB-Id	**CS**	**Index**		**Sub-Index**	**Data**			
→ Request: Control Unit to Sensor								
600h + Node-Id	Byte	LSB	MSB	Byte	LSB	..	..	MSB
← Response: Sensor to Control Unit								
580h + Node-Id	Byte	LSB	MSB	Byte	LSB	..	..	MSB

SDO - Download Protocol

8 Byte data frame							
CS	**Index**		**Sub-Index**	**Data**			
→ Request: Control Unit to Sensor							
ccs	LSB	MSB	Byte	LSB	..	..	MSB
← Response: Sensor to Control Unit							
scs	LSB	MSB	Byte	Reserved			

Bit structure of command specifier CS:

b7	b6	b5	b4	b3	b2	b1	b0
→ Request: Control Unit to Sensor							
ccs			X	n		e	s
← Response: Sensor to Control Unit							
scs			X				

ccs: control unit command specifier, ccs = 1 (=> CS_8 = 2Fh, CS_{16} = 2Bh, CS_{32} = 23h)
scs: sensor command specifier, scs = 3 (=> CS = 60h)
X: reserved
e: expedited transfer e = 1
s: data set size = 1
n: number of bytes which do not contain data

SDO - Upload Protocol

8 Byte data frame			
CS	**Index**	**Sub-Index**	**Data**

→ **Request: Control Unit to Sensor**

scs	LSB	MSB	Byte	Reserved

← **Response: Sensor to Control Unit**

ccs	LSB	MSB	Byte	LSB	..	..	MSB

Bit structure of command specifier CS:

b7	**b6**	**b5**	**b4**	**b3**	**b2**	**b1**	**b0**

→ **Request: Control Unit to Sensor**

scs	X

← **Response: Sensor to Control Unit**

ccs	X	n	e	s

ccs: control unit command specifier, ccs = 2 (=> CS = 40h)
scs: sensor command specifier, scs = 2 (=> CS_8 = 4Fh, CS_{16} = 4Bh, CS_{32} = 43h)
X: reserved
e: expedited transfer e = 1
s: data set size = 1
n: number of bytes which do not contain data

SDO - Abort Peer-to-Peer-Protocol

8 Byte data frame			
CS	**Index**	**Sub-Index**	**Data**

→ **Response: Control Unit or Sensor**

cs	LSB	MSB	Byte	Abort Code

Bit structure of command specifier CS for Abort Protocol:

b7	**b6**	**b5**	**b4**	**b3**	**b2**	**b1**	**b0**

→ **Request: Control Unit to Sensor**

cs	X

cs: control unit / sensor command specifier, cs = 4, (=> CS = 8h)
X: reserved

SDO - Abort Code Description

Abort Code	Description
0601 0001h	Attempt to read a write only object.
0601 0002h	Attempt to write a read only object.
0602 0000h	Object does not exist in the object dictionary.
0604 0043h	General parameter incompatibility
0607 0012h	Data type does not match, length of service parameter too high
0607 0013h	Data type does not match, length of service parameter too low
0609 0030h	Value range of parameter exceeded (only for write access).

Process Data Message (TPDO)

Process data messages are broadcast messages. The structure of the 8 Byte data frame is product specific.

11-Bit CAN-Id	8 Byte data frame
PDO COB-Id	Process Data

← Sensor to Control Unit

180h + Node-Id	LSB	…					..	MSB

Format of Process Data Field

B0	B1	B2	B3	B4	B5	B6	B7
Position value							Error Register
LSB	...	...	MSB	reserved	reserved	reserved	Byte

Bit structure of object 1001, Error Register

b7	b6	b5	b4	b3	b2	b1	b0
							Generic

b0 Generic Error
0: No Error
1: Internal Error or Communication Error

TPDO Transmit-PDO Transmission Type

Transmission type of TPDO-1, -2 is configurable by object PDO Communication Parameter 1800, 1801 sub-indices -1, -2, -3 and -5.

Transmission type example for TPDO-1	COB-Id 1800-1	Transmission Type 1800-2	Inhibit Time 1800-3	Event Timer [ms] 1800-5
Event Timer Driven	1FFh	FEh	0 ... FFFFh	0 ... FFFFh
Cyclic Synchronous	1FFh	N = 1 ... F0h		-
TPDO Disable	80 00 xx xx	-		-
TPDO Enable	00 00 xx xx	-		-

Transmission type "Event Timer Driven" triggers TPDO-transmission periodically with a time period defined by the event timer. In "Cyclic Synchronous" a TPDO is transmitted on reception of a number of one or multiple SYNC commands. Enable or disable a TPDO by setting Bit 31 of the COB-Id '0' resp. '1' (Default: "0" Enabled).

Communication Profile CiA 301

Object	Index [hex]	Sub-idx	Access	Type	Default	Value Range / Note [time spec in ms]
Device type	1000	0	ro	U32	2019Ah	inclinometer profile, 410
Error register	1001	0	ro	U8	0	
COB-ID-Sync	1005	0	rw	U32	80	
Manufacturer device name	1008	0	ro	String	-	
Manufacturer hardware version	1009	0	ro	String	-	
Manufacturer software version	100A	0	ro	String	-	
Guard time	100C	0	rw	U16	0	0 .. 7FFFh
Life time factor	100D	0	rw	U8	0	0 .. FFh
Save Settings	1010	1	w	U32	-	„save“ 65766173h
Load Manufacturer Settings	1011	1	w	U32	-	„load“ 64616F6Ch*)
COB-ID-EMCY	1014	0	ro	U32	FFh	NodeID+80h
Producer heartbeat time	1017	0	rw	U16	0	0 .. 7FFFh
Identity Object VendorID	1018	1	ro	U32	252h	
Identity Object Product Code		2	ro	U32	-	
Identity Object Revision number		3	ro	U32	-	
Identity Object Serial number		4	ro	U32	-	
COB-ID Server->Client	1200	1	ro	U32	67Fh	SOD
COBID Client-> Sever	1200	2	ro	U32	5FFh	SDO
PDO1 COB-ID	1800	1	rw	U32	1FFh	181h .. 1FFh
PDO1 Transmission-Type		2	rw	U8	FEh	0 .. FFh
PDO1 Inhibit time		3	rw	U16	0	0 .. 7FFFh
PDO1 Event timer		5	rw	U16	0	0 .. 7FFFh
TPDO1-Mapped Object 1	1A00	1	ro	U32	60100010h	
TPDO1-Mapped Object 2		2	ro	U32	60200010h	
NMT-Startup	1F80	0	rw	U32	0	0,8

*) Reload factory defaults does not affect Node-Id

Device Profile

Object	Index [hex]	Sub-index	Access	Type	Default	Value Range / Note
Manufacturer specific						
Node-ID	2000		rw		127	1…127
Bitrate	2010		rw		4	0..4, 6
Error	2030		ro			
Hysteresis	2040		rw			
Bus termination	2050				0	0: OFF , 1: ON (PTDM27 only)
Filter (N_{Filter}) Response Time (90%): $T_R = N_{Filter}$* 5 ms	2102		rw		0*	0 ... 65535
Inclinometer CiA410						
Resolution (in 0,001°)	6000		rw		100	10 ... 10000
Slope long16 inclination angle round x axis	6010					
Oper. parameters slope long16, 1 or 2 axes	6011				0	
Slope long16 preset value	6012				0	
Slope lateral16 inclination angle round y axis	6020					
Oper. parameters slope lateral16, 2nd axis	6021				0	
Slope lateral16 preset value	6022				0	

*) Preconfigured to 16

Operating Parameters Bit Code

7	...	2	1	0
m			s	cs
MSB				LSB

cs = 0/1 Code sequence CW/CCW
s = 0/1 Scaling function enabled/disabled
m = 0/1 Operating mode: 1 axis x ±180°/2 axes x,y ±60°

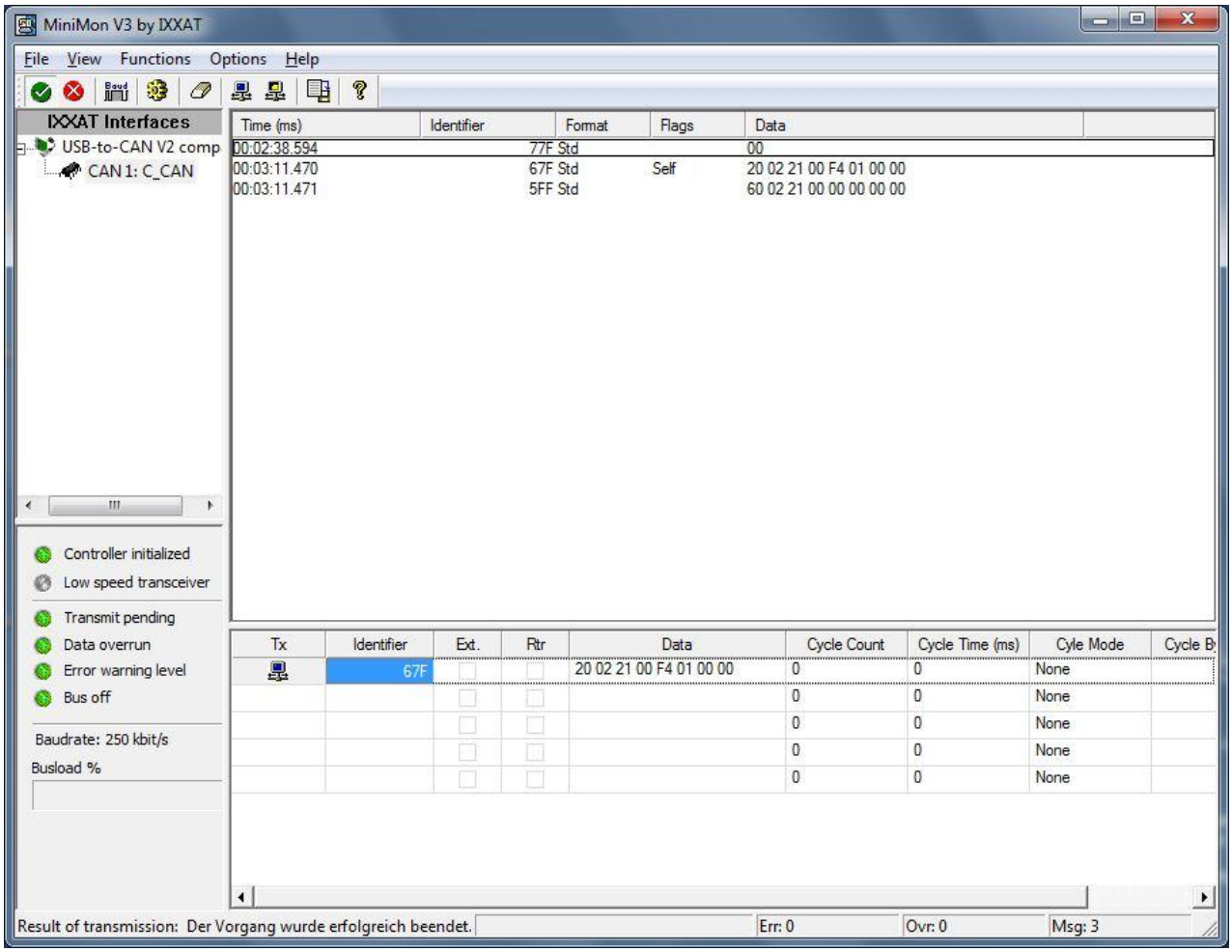
Baud Rate (Object 2010)

Baud Rate Index	Baud Rate [kbit/s]
0	1000
1	800
2	500
3	250
4	125

CANopen example protocols

The example protocols are prepared using the USB-to-CAN Interface with CAN-Monitor „IXXAT“ (HMS Industrial Networks AB). The examples enable the user to configure and run the CANopen sensor from a host PC without using a CANopen master ECU.

CAN Monitor Screen



Example: boot up and change parameter

Time (ms)	Identifier	Format	Flags	Data
00:02:38.594	77F	Std		00
00:03:11.470	67F	Std	Self	20 02 21 00 F4 01 00 00
00:03:11.471	5FF	Std		60 02 21 00 00 00 00 00

After boot up (line 1) the filter (Object 2102-00) will be changed to 1F4h by an SDO message (line 2). The sensor sends a response message (line 3).

Example: change Node-ID

Time (ms)	Identifier	Format	Flags	Data
00:14:34.540	77F	Std		00
00:14:36.969	67F	Std	Self	2F 00 20 00 7E 00 00 00
00:14:36.970	5FF	Std		60 00 20 00 00 00 00 00
00:14:38.633	67F	Std	Self	23 10 10 01 73 61 76 65
00:14:38.637	5FF	Std		60 10 10 01 00 00 00 00
00:14:41.486	77E	Std		00

After boot up (line 1) the node-ID (2000h) will be changed from 7F to 7Eh by SDO (line 2, 3). The changed setting is stored nonvolatile by SDO "SAVE" (line 4). The sensor node-ID stays unchanged (Line5, 6) and will become valid on next power down - boot up cycle (line 6). Note: While the configurable parameters will become valid immediately node-ID and baud rate stay unchanged until the next power cycle.

Example: switch to operational

Time (ms)	Identifier	Format	Flags	Data
00:00:41.658	77F	Std		00
00:00:46.441	0	Std	Self	01 00
00:00:46.441	1FF	Std		2F 1A 00 00
00:00:46.542	1FF	Std		2F 1A 00 00
00:00:46.643	1FF	Std		2F 1A 00 00
00:00:46.743	1FF	Std		2F 1A 00 00
00:00:46.843	1FF	Std		2F 1A 00 00

After boot up (line 1) a "Start all Nodes" NMT message (line 2) will switch the sensor from pre-operational to operational starting transmission of the process data objects (lines 3...).

Example: change COB-ID of a TPDO

Time (ms)	Identi...	Format	Flags	Data
00:50:43.447	77F	Std		00
00:50:43.447	77E	Std		00
00:51:54.461	67F	Std	Self	23 00 18 01 00 00 00 80
00:51:54.463	5FF	Std		60 00 18 01 00 00 00 00
00:51:59.317	67F	Std	Self	23 00 18 01 81 01 00 00
00:51:59.319	5FF	Std		60 00 18 01 00 00 00 00

The example sequence shows boot up of node 7Fh in line 1. Write access is enabled be writing 80000000h to COB-ID object, Index 1800-1 (lines 3, 4). Next frame writes a new COB-ID 181h to Index 1800-1 (lines 5, 6).

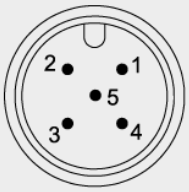
Example: change transmission type of a TPDO

Time (ms)	Identi...	Format	Flags	Data
00:03:41.266	77F	Std		00
00:03:41.266	77E	Std		00
00:03:47.981	67F	Std	Self	23 00 18 01 00 00 00 80
00:03:47.983	5FF	Std		60 00 18 01 00 00 00 00
00:03:55.413	67F	Std	Self	2F 00 18 02 01 00 00 00
00:03:55.414	5FF	Std		60 00 18 02 00 00 00 00
00:04:02.309	67F	Std	Self	23 00 18 01 FF 01 00 00
00:04:02.311	5FF	Std		60 00 18 01 00 00 00 00

The example sequence shows boot up of node 7Fh in line 1. Write access is enabled be writing 80000000h to COB-ID object, Index 1800-1 (lines 3, 4). Next two frames write a new Transmission Type 1h to Index 1800-2 (lines 5, 6) and restore the COB-ID object, Index 1800-1 to its original value 1FFh (lines 7, 8).

CANJ1939 SAE J1939 	CAN specification	ISO 11898, Basic and Full CAN 2.0 B	
	Transceiver	24V-compliant, not isolated	
	Communication profile	SAE J1939	
	Transmission rate	250 kbit/s	
	Address	Default 247d, configurable	
NAME Fields	Arbitrary address capable	1	Yes
	Industry group	0	Global
	Vehicle system	7Fh (127d)	Non specific
	Vehicle system instance	0	
	Function	FFh (255d)	Non specific
	Function instance	0	
	ECU instance	0	
	Manufacturer	145h (325d)	Manufacturer ID
	Identity number	0nnn	Serial number 21 bit
Parameter Group Numbers (PGN)	Configuration data	PGN EF00h	Proprietary-A (PDU1 peer-to-peer)
	Process data	PGN FFnnh	Proprietary-B (PDU2 broadcast); nn Group Extension (PS) configurable

Specifications	Excitation voltage	8 ... 36 V DC
	Excitation current	15 mA typical at 24 V DC 30 mA typical at 12 V DC 100 mA max.
	Measuring rate	1 kHz (standard)
	Stability (temperature)	±100 x 10^{-6} / °C f.s.
	Repeatability	1 LSB
	Operating temperature	-40 … +85 °C
	Protection	Reverse polarity, short circuit
	EMV	DIN EN 61326-1:2013

Signal wiring Connector M12, 5 pin	Output signals	Connector pin no.
 View to the sensor connector	Shield	1
	Excitation +	2
	GND	3
	CAN-H	4
	CAN-L	5

Overview Boot-Up, User Configuration, Process Data

Address Claiming (Single Address capable device)

On power up the sensor claims a Node Address by sending an *Address Claimed* message which contains the NAME as a unique identifier. Should another device claim the same address the device having the NAME with a lower priority will send *Cannot Claim Address* and stay passive.

User configuration

User accessible parameters are configurable by peer-to-peer proprietary-A message (PGN EF00h). The configuration parameters are accessed by a standard message format. The Node Address is configurable either by *Commanded Address* or by peer-to-peer proprietary-A message. A new address set by peer-to-peer proprietary-A message will be effective not before next power up. A new address set by *Commanded Address* will be effective immediately and an *Address Claimed* message will be sent. On execution of *Store Parameters,* the configuration is saved nonvolatile.

Process Data

Process Data are transmitted cyclic by Broadcast PGN FFnnh on power up after successful address claiming. The cycle time and the Group Extension Byte nn (PS) are user configurable.

⚠ WARNING **Risk of injury by unexpected machine movement!**

- Changing parameters may cause unexpected machine movement.
- Changing parameters may influence dependent parameters e.g. changing the resolution may have influence on position of CAM switches.
- Precautions have to be taken to avoid damage to human and machine parts!
- Change parameters only when machine is in a safe condition!

Peer-to-peer message (PGN 0x00EF00), send/receive format

	PGN		8 Byte data frame							
	PGN_{HIGH}	PGN_{LOW} (Node-ID)	Index	Rd/Wr	0	Ack	4-Byte Data			
Request: Control Unit → Sensor										
→	0EFh	dd	i	0/1	0	0	LSB	..	..	MSB
Response: Control Unit ← Sensor										
←	0EFh	cc	i	0/1	0	a	LSB	..	..	MSB

a: Acknowledge codes:
0: Acknowledge, 81: Read only parameter, 82: Range overflow,
83: Range underflow, 84: Parameter does not exist

dd: Sensor Node-ID (Default 0F7h, 247d)

cc: Control-Unit Node-ID

Configuration examples

Example: Set Transmit Cycle to 10ms, Index 31, Node-ID 247d (F7h)

	PGN_{HIGH}	PGN_{LOW}	8 Byte data frame							
→	0EFh	F7h	1Fh	01h	00	00	0Ah	00	00	00
←	0EFh	cc	1Fh	01h	00	00	0Ah	00	00	00

Example: Read Transmit Cycle value, Index 31

→	0EFh	F7h	1Fh	00	00	00	00	00	00	00
←	0EFh	cc	1Fh	00	00	00	0Ah	00	00	00

Example: Store Parameters permanently, Index 28

→	0EFh	F7h	1Ch	01h	00	00	65h	76h	61h	73h
←	0EFh	cc	1Ch	01h	00	00	65h	76h	61h	73h

Reload factory defaults, Index 29

→	0EFh	F7h	1Dh	01h	00	00	64h	61h	6Fh	6Ch
←	0EFh	cc	1Dh	01h	00	00	64h	61h	6Fh	6Ch

Example: Broadcast (PGNLow = 0FFh - Reload factory defaults of all sensors, Index 29

→	0EFh	0FFh	1Dh	01h	00	00	64h	61h	6Fh	6Ch
←	0EFh	cc	1Dh	01h	00	00	64h	61h	6Fh	6Ch

Configurable parameters

Parameter	Index [hex]	Sub-Index [hex]	Read / Write	Type	Default	Range / Selection [Unit]
Control						
Store parameters	1010	1	wo [2])	U32	-	“save”
Reload factory defaults	1011	1	wo [2])	U32	-	“load”
Node Address	2000	0	rw [1])	U8	F7h	80h..F7h
PGN Group Extension (PS)	2001	0	rw	U8	0	0..255
Bit Rate	2010	0	ro	U8	3	250 kBit/s
Termination Resistor	2050	0	rw	U8	0	0=OFF, 1=ON
Mounting Option [5])	2110	0	rw	U8	1	1=2A, 2=2B, 3=2C
Low Pass Output Filter	2103	0	rw	U16	0	0 ... 65535
Measurement						
Resolution (in steps of 0.001°)	6000	0	rw	U16	10	10, 100, 1000
Slope long16 inclination angle round x axis	6010	0	ro	I16	no	-180 ... +180 [°]
Operating parameters slope long16 [4])	6011	0	ro / rw [3])	U8	0	
Slope long16 preset value	6012	0	rw	I16	0	-180 ... +180 [°]
Slope lat16 inclination angle round y axis	6020	0	ro	I16	no	-180 ... +180 [°]
Operating parameters slope lat16 [4])	6021	0	ro / rw [3])	U8	0	
Slope lat16 preset value	6022	0	rw	I16	0	-180 ... +180 [°]
Cyclic timer	6200	0	rw	U16	100	$0..2^{16}$-1 ms
Identification						
SW Version	2F05	0	ro	U32	-	
Serial number	2F00 2F01	0 0	ro	U32 U32	-	
Idendity Number	2002	0	ro	U32	-	

[1]) Effective after "store parameters" and next power-up
[2]) “save”: LSB...MSB: 73h 61h 76h 65h
“load”: LSB...MSB: 6Ch 6Fh 61h 64h
Reload factory defaults does not affect Node-Id and Bit Rate
[3]) Write access to objects 6012, 6022 only when scaling function enabled (Object 6011, 6021)
[4]) See Table below
[5]) Set preset to 0 for both axes while the sensor is in the new zero-position

Bit structure of object 6011, 6021, operating parameters:

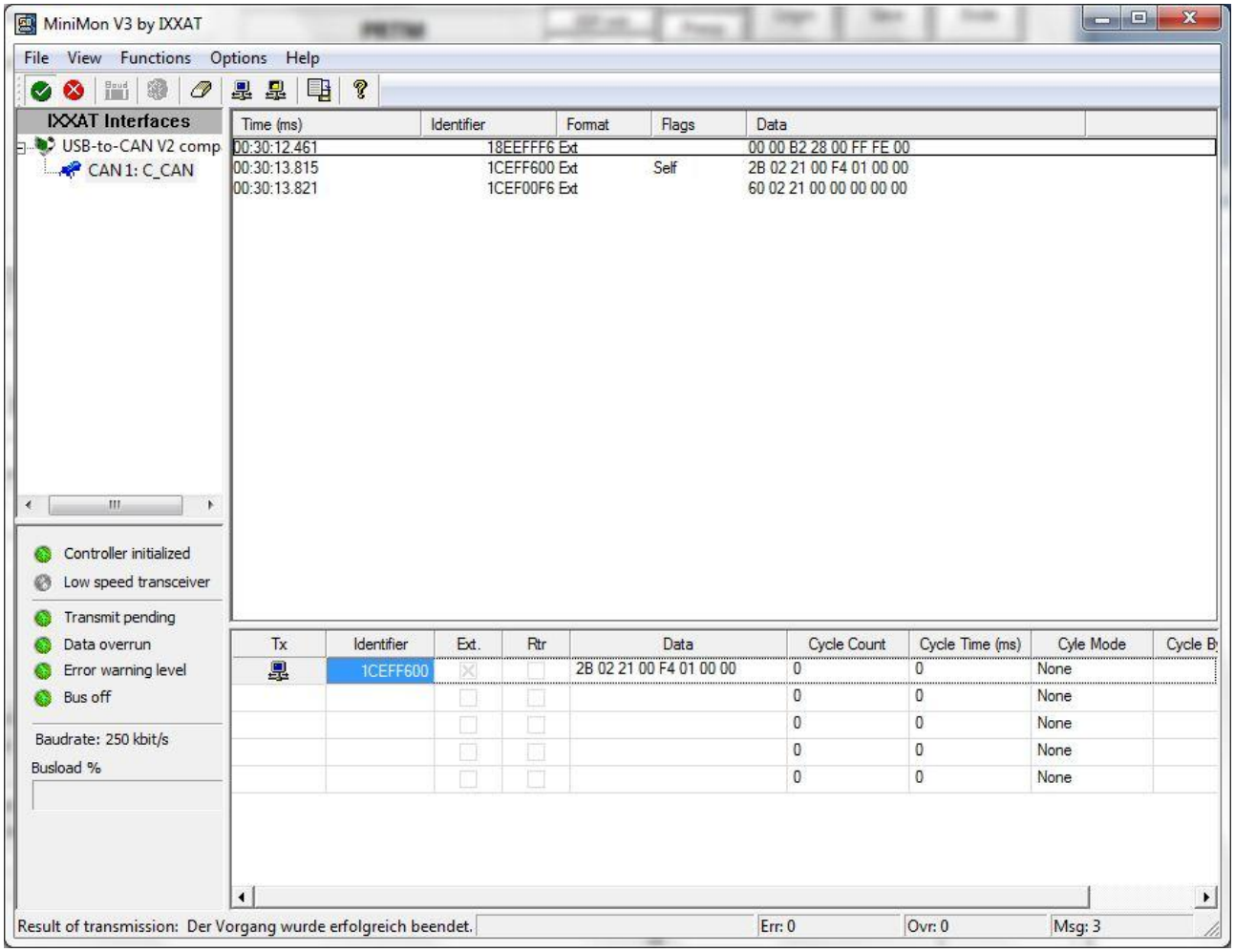
Bit7	Bit6	Bit5	Bit5	Bit4	Bit3	Bit2	Bit1
ms			r			s	i

i Slope Inversion
0: slope inversion disabled
1: slope inversion enabled
s Scaling Enable
0: scaling disabled
1: scaling enabled
r reserved
ms Manufacturer specific

SAE J1939 Example Protocols

The example protocols are prepared using the USB-to-CAN Interface with CAN-Monitor „IXXAT“ (HMS Industrial Networks AB). The examples enable the user to configure and run the CANopen sensor from a host PC without using a CANopen master ECU.

CAN Monitor Screen



Example: Address-Claiming and Change Parameter

Time (ms)	Identifier	Format	Flags	Data
00:30:12.461	18EEFFF6	Ext		00 00 B2 28 00 FF FE 00
00:30:13.815	1CEFF600	Ext	Self	2B 02 21 00 F4 01 00 00
00:30:13.821	1CEF00F6	Ext		60 02 21 00 00 00 00 00

After boot up the sensor claims address F6h by "Address Claim" message (line 1). The filter (Object 2102-00) will be changed to 1F4h by a configuration message (line 2) and the sensors sends a response message (line 3),

Example: Change Node-ID

Time (ms)	Identifier	Format	Flags	Data
00:33:31.336	18EEFFF6	Ext		00 00 B2 28 00 FF FE 00
00:33:32.195	1CEFF600	Ext	Self	2F 00 20 00 F4 00 00 00
00:33:32.196	1CEF00F6	Ext		60 00 20 00 00 00 00 00
00:33:33.459	1CEFF600	Ext	Self	23 10 10 01 73 61 76 65
00:33:33.475	1CEF00F6	Ext		60 10 10 01 00 00 00 00
00:33:34.670	18EEFFF4	Ext		00 00 B2 28 00 FF FE 00

After boot up and address claim (line 1) the node-ID (2000h) will be changed from F6h to F4h (line 2, 3). The changed setting is stored nonvolatile by "SAVE" (line 4, 5). The sensor node-ID stays unchanged (Line 5, 6) and will become valid on next power up cycle (line 6). Note: While the configurable parameters will become valid immediately node-ID and baud rate stay unchanged until the next power cycle.

Example: Autostart

Time (ms)	Identifier	Format	Flags	Data
00:21:20.412	18EEFFF6	Ext		00 00 B2 28 00 FF FE 00
00:21:20.605	18FF00F6	Ext		59 00 00 00 00 00 00 80
00:21:20.805	18FF00F6	Ext		ED 3F 00 00 00 00 00 80
00:21:21.005	18FF00F6	Ext		0C 00 00 00 00 00 00 80
00:21:21.205	18FF00F6	Ext		F0 3E 00 00 00 00 00 80
00:21:21.405	18FF00F6	Ext		0B 00 00 00 00 00 00 80
00:21:21.605	18FF00F6	Ext		84 00 00 00 00 00 00 80

After boot up (line 1) a "Start all Nodes" message (line 2) will switch all sensors from pre-operational to operational starting the transmission of the process data objects (lines 3...).