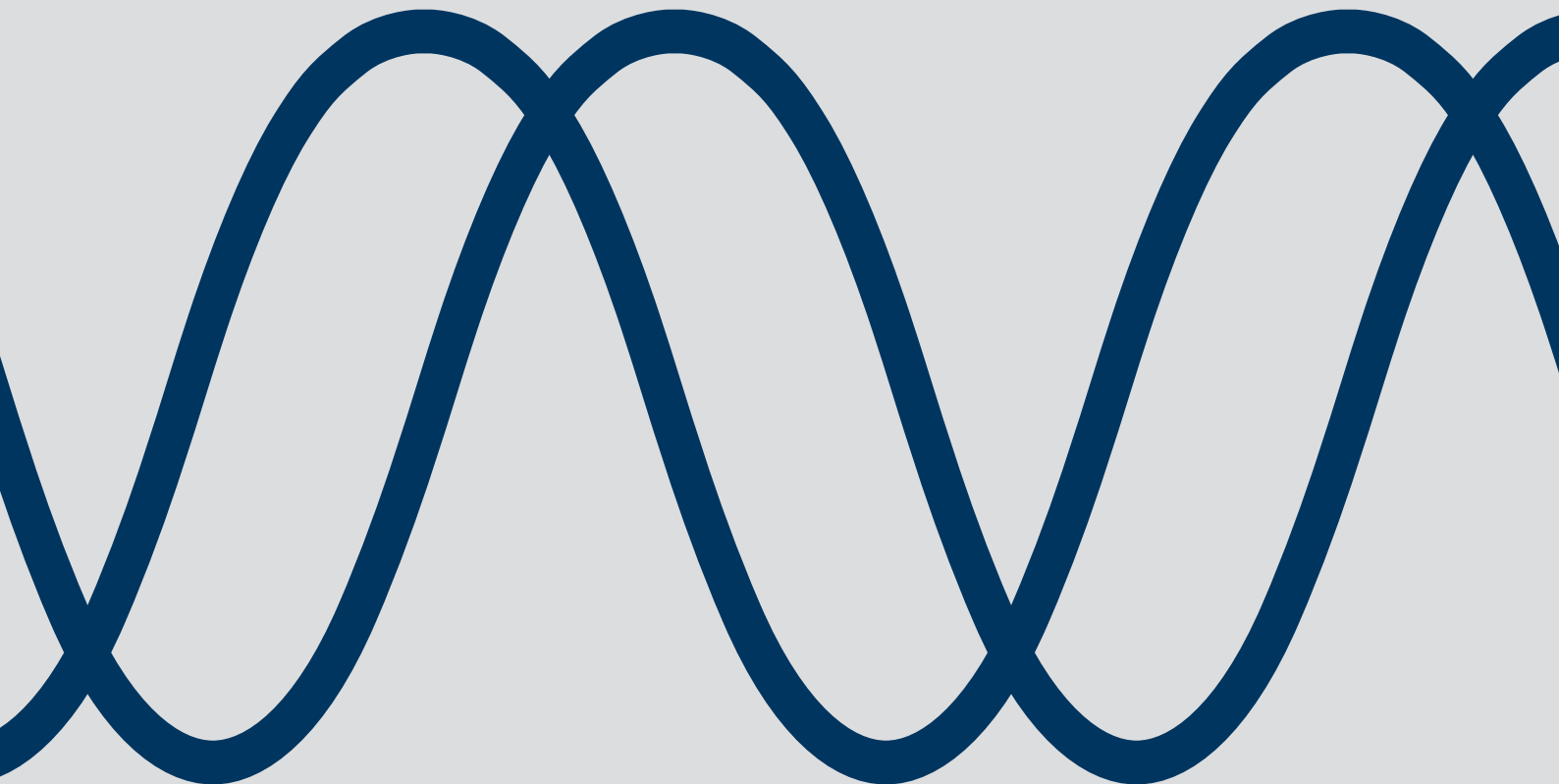




EtherCAT[®]

FOR 600, 900 SERIES ENCODERS

MANUAL / USERS GUIDE



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LEINE  LINDE

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and patented technology, licensed by
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1 General information

Thank you for choosing this device produced by the Swedish encoder manufacturer Leine Linde. In your hands, you have a state-of-the-art component that is ready to be used in the utmost demanding environments.

This manual describes the installation and configuration procedure of absolute encoders with EtherCAT® interface. If you are in need of assistance during the system design phase, commissioning, or during operation, please make sure that you contact your nearest Leine Linde representative.



1.1 About absolute encoders

With an absolute encoder each angular position is assigned a coded position value generated by optical or inductive scanning. The optical encoder has a code disc equipped with several fine graduations tracks which are scanned as a pattern that is specific for every position. The inductive encoder has a stator and rotor. It works with electromagnetic inductance meaning that electric current is generated in an electrical conductor, if a magnetic field varies within its present generating signals.

Absolute encoders can be singleturn or multiturn. Singleturn encoders produce absolute positions within one revolution, the absolute position information repeats itself with every revolution. Multiturn encoders can also distinguish between revolutions. The numbers of unique revolutions is determined by the resolution of the multiturn scanning and repeats itself after the total resolution is reached. A major benefit of the absolute encoder type is that if the encoder loses power, the encoder is able to keep track of its position also if the shaft is turned during the power loss. This is due to the genuine absolute scanning principle.

An absolute encoder can also be used to calculate a digital speed value. By internally dividing the difference in position with a small delta time an accurate speed value can be calculated and transmitted to the subsequent electronics for closed loop control.

1.2 Applicability of manual

The instructions in this product manual apply to Leine Linde's absolute encoders within the following encoder series:

ISA 607	IHA 607	PSE 901	PHE 901
ISA 608	IHA 608	PSE 903	PHE 903
ISA 697	IHA 697	PSE 991	PHE 991
ISA 698	IHA 698	PSE 993	PHE 993

1.3 EtherCAT® technology

The EtherCAT solution is faster and more efficient than other Ethernet solutions. This is achieved by letting each slave on the bus only read the data which is addressed to their node ID while the data packet passes through the node.

EtherCAT® is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

1.3.1 Flexible topologies

Line, tree, or star configuration: EtherCAT supports almost any topology, see figure 1. The bus or line structures typically seen in the fieldbuses also become available for Ethernet with the use of EtherCAT. Particularly useful for system wiring is the combination of lines and branches or stubs. The required interfaces exist on the couplers; no additional switches are required.

Flexible and inexpensive Industrial Ethernet fieldbus cables transfer signals in Ethernet mode (100BASE-TX) up to a cable length of 100 m between two devices. The complete bandwidth of the Ethernet network – such as different optical fibres and copper cables – can be used in combination with switches or media converters. Since up to 65,535 devices can be connected, the size of the network is almost unlimited.

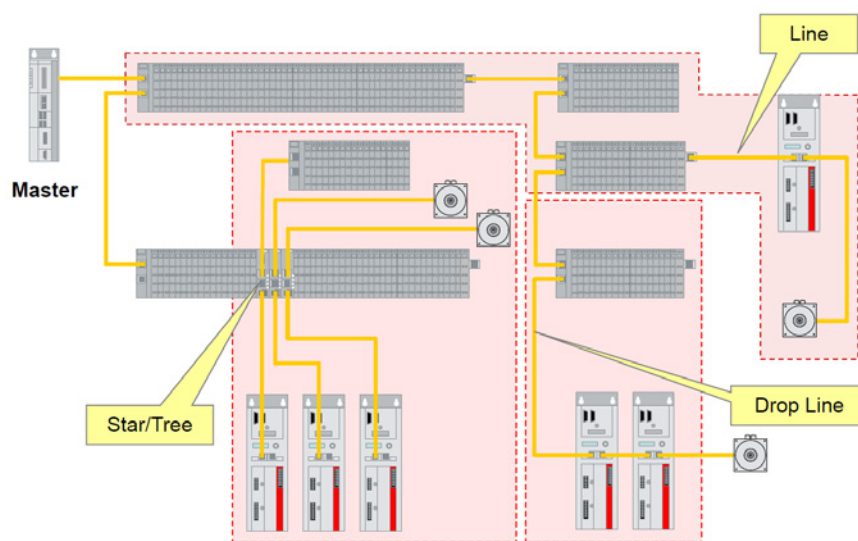


Figure 1 Various possible topologies

1.3.2 Protocol

The EtherCAT protocol, optimized for process data, is transported directly in the Ethernet frame via a special Ether type, see figure 1. A complete transmission can consist of several sub-frames. The data sequence is independent of the physical sequence of the slaves in the network. The addressing can be freely selected:

Broadcast, multicast, and lateral communication between slaves are possible.

The protocol also supports non-cyclical parameter communication. The structure and meaning of the parameters is predetermined by the device profile "CANopen Device Profile for Encoder CiA DS-406".

UDP/IP datagram is not supported. Therefore the master and the EtherCAT slaves must be located in the same subnet. Communication across routers into other subnets is not possible.

EtherCAT exclusively uses standard frames in accordance with IEEE 802.3 without shortening. This means that EtherCAT frames can be sent by any Ethernet controller (master), and standard tools such as monitors can be used.

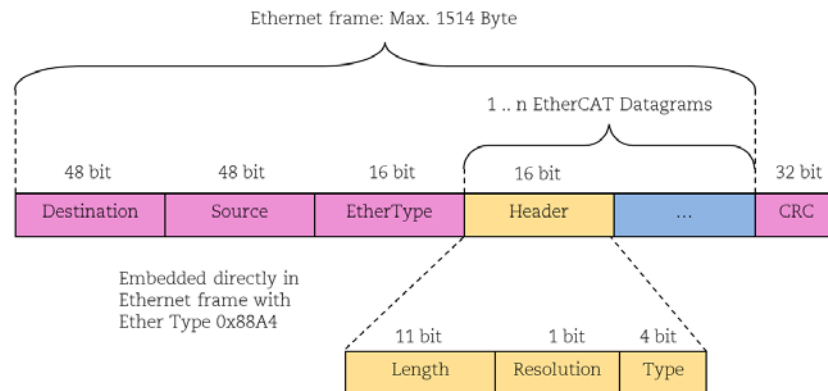


Figure 2 Ethernet frame structure

1.4 About Leine Linde

Leine Linde is a Swedish company with international presence. For more than 50 years, Leine Linde has concentrated on development and manufacturing of advanced encoders that meet the most rigorous demands a user can place on them. That is why a wide assortment of incremental and absolute encoders with obvious concentration on robust products and quality down to the last detail can be offered. Leine Linde encoders provide the utmost in reliability year after year, in working conditions where vibration, dirt, cold and other harsh environments are common.

Leine Linde can meet very specific individual demands. Due to a modular design in the collection, the encoders are easily adapted exactly to the customer's needs with respect to resolution, electrical connections and interfaces, voltage, casings, etc. Leine Linde concentrates on advanced development of intelligent encoders with integrated ASICs, new special features and with adaptations to different fieldbus systems. Thereby the company can meet the need for increasingly effective and dependable machines and automation to an even higher degree.

1.4.1 Technical and commercial support

Leine Linde is represented by subsidiaries in many countries around the world. In addition, there are many service agencies and distributors located worldwide ready to reply to commercial enquiries or technical support. For more contact information, please visit our web site at <http://www.leinelinde.com> or contact Leine Linde in Strängnäs, Sweden.

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1.5 Abbreviations

CAN	Controller Area Network	HR	High Resolution
CiA	CAN in Automation	PDO	Process Data Object
CoE	CANopen over EtherCAT	SDO	Service Data Object
ESI	EtherCAT Slave Information	SR	Standard Resolution
FoE	File Access over EtherCAT		

2 Encoder installation

2.1 Cables and standards

Suitable connection cables are class D according to EN 50173, category 5 quality or higher.

The recommended maximum cable length between each unit is 100 metres. Since up to 65,535 devices can be connected, the size of the network is almost unlimited.

Leine Linde provides cables and accessories for use with EtherCAT encoders. For more information see website www.leinelinde.com or contact info@leinelinde.se.

2.2 Connectors and pin configuration

M12 connectors are used for EtherCAT data communication from the encoder, constituted by a 4-pin female shielded D-coded version. The correct arrangement of the bus connectors is specified in table 1:

Function	Pin
M12 D-coded 4p (out)	
TX+	1
RX+	2
TX-	3
RX-	4
M12 D-coded 4p (in)	
TX+	1
RX+	2
TX-	3
RX-	4
M12 A-coded 4p male (supply)	
+EV	1
0V	3

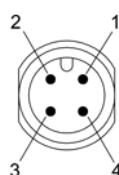


Table 1 Pin configuration

2.3 Shielding concept of the device

Automation systems in industrial environments can be subjected to high levels of electromagnetic disturbances. Each and every component in the automation system must be designed to still guarantee continuous and uninterrupted function.

Data cabling is considered a passive system and cannot be tested for EMC compliance. However, cabling and connection elements for EtherCAT support comply with device requirements in order to provide a high-quality,

comprehensive shielding concept.

To achieve the highest possible noise immunity and resistance against other EMC related disturbances, the bus and power supply cables must always be shielded. The shield should be connected to ground on both ends of the cable. In certain cases, compensation current may flow over the shield.

2.4 ESI file description and file installation

The configuration example in this manual is based on TwinCAT manager, developed by Beckhoff. If another configuration tool is used, please consult your tool supplier for more information.

2.4.1 ESI file

An ESI file (EtherCAT Slave Information) is available for download at our homepage www.leinelinde.se. Note that there are different versions of ESI files depending on the encoder model you are using. Due to Leine Linde's constant drive to support our customers with the latest updates of encoder functionality it is recommended to consult Leine Linde representatives for the latest releases.

The ESI file describes:

- Communication functionality and objects as defined in the CANopen® communication profile DS-301.
- Device-specific objects as defined in the CANopen Encoder Profile DS-406.
- Manufacturer-specific objects which will be described in this manual.

Note: The ESI installation procedure depends on your configuration tool, please consult your tool provider if problems occur.

File installation

Before configuration of the EtherCAT device, the ESI files must be copied into the directory of the Beckhoff TwinCAT Manager. A restart of the software is required after the ESI files are copied into the directory. The files should always be unpacked completely into the ESI-directory of the EtherCAT master.

For TwinCAT versions 2.x the files should be placed in: \TwinCAT\IO\EtherCAT

For TwinCAT versions 3.x the files should be placed in: \TwinCAT\3.x\Config\Io\EtherCAT

For other masters/configuration tools please refer to the description specific to your manufacturer.

2.5 LED indication

defines diagnostic indications shown by the Leine Linde encoder's four bi-coloured LEDs.

Colour	LED	
	MODULE	Description
	OFF	No power
Green	ON	OK
Red	ON	Position error, the encoder is not able to give a correct position value.

Colour	LED	
	STATUS	Description
	OFF	The encoder is in state INIT/the EtherCAT communication of the encoder is in working condition.
Green	Blinking	The encoder is in state PRE-OPERATIONAL
Green	Single flash	The encoder is in state SAFE-OPERATIONAL
Green	ON	The encoder is in state OPERATIONAL
Green	Flickering	The encoder is booting and has not yet entered the INIT state, or: The encoder is in state BOOTSTRAP. Firmware download operation in progress.
Red	Double flash	An application watchdog timeout has occurred.
Red	Single flash	Slave encoder application has changed the EtherCAT state autonomously, due to local error (see ETG, 1000 part 6 EtherCAT State Machine). Error Indicator bit is set to 1 in AL Status register.
Red	Blinking	General configuration error/invalid configuration.
Red	Flickering	Bootling Error was detected. INIT state reached, but Error Indicator bit is set to 1 in AL Status register.
Red	ON	A critical communication or application controller error has occurred.
	L/A In	Description
Green	ON	Port open, Link: YES, Activity: NO
Green	Flickering	Port open, Link: YES, Activity: YES
	OFF	Port closed, Link: NO, Activity: Not applicable
	L/A Out	Description
Green	ON	Port open, Link: YES, Activity: NO
Green	Flickering	Port open, Link: YES, Activity: YES
	OFF	Port closed, Link: NO, Activity: Not applicable

Table 2 Encoder LED indication

3 Encoder functionality

Figure 3 describes basic encoder functionality, how objects relate to each other, and the functionality they provide.

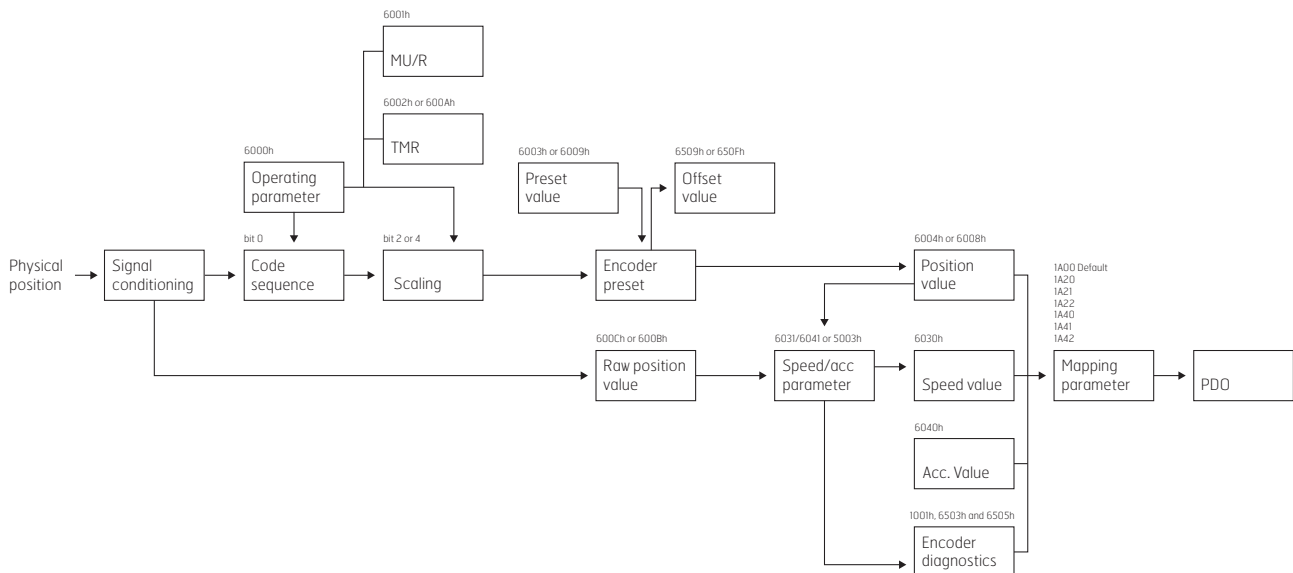


Figure 3 Rotational encoder functionality

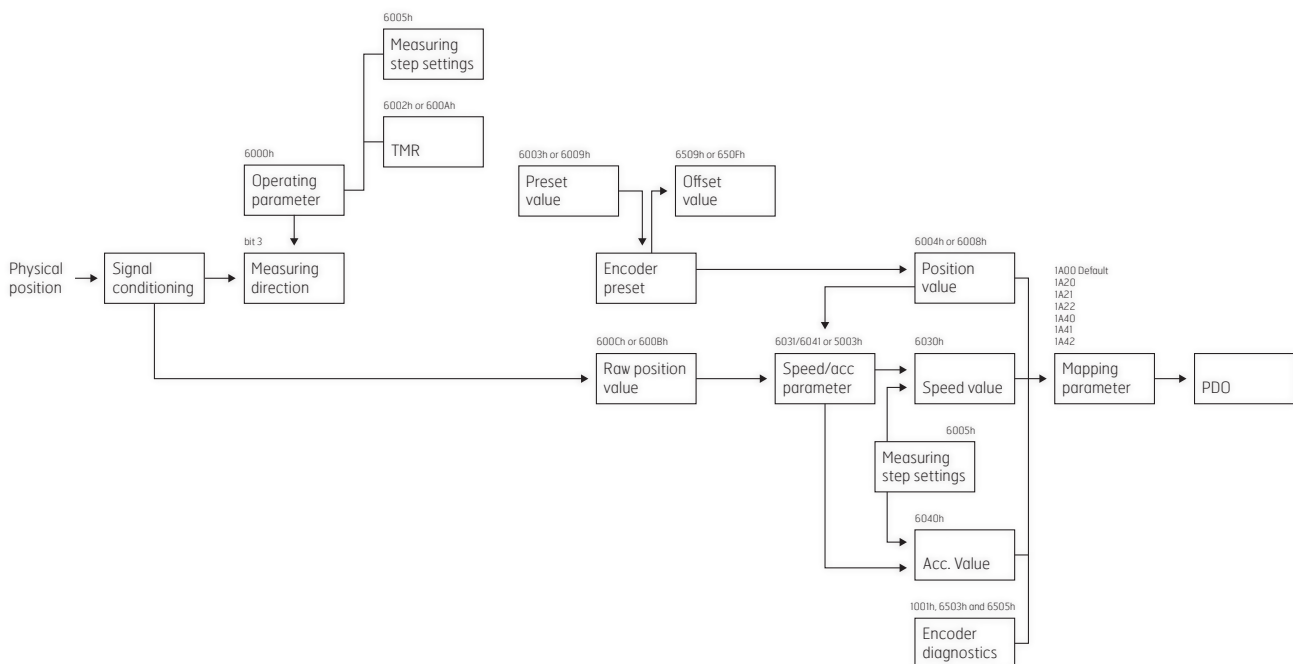


Figure 4 Linear encoder functionality

3.1 Parameterization

Parameters can be set from the configuration tool when the device is in the Pre-Operational state using the objects described in the ESI-file. The parameters can also be changed during runtime (Operational state). Please be careful as the position data is directly affected by some parameters and will change immediately following such a parameter message. We advise that you only change the scaling function parameters and the code sequence at encoder standstill.

Note: The parameterization procedure depends on your configuration tool, please consult your tool supplier if problems occur.

3.2 EtherCAT State machine

The slave runs a state machine to indicate which encoder functionalities are available, refer to table 3.

State	Available functions
INIT	Initial state. Encoder starts and previously stored values are loaded. No communication on the application layer is available. The master has access only to the DL-information registers.
PREOP	Pre-operational, the encoder is ready for its parameters to be programmed. SDO transfer can begin. Mailbox communication on the application layer is available. No process data communication available.
SAFEOP	Safe-operational, EtherCAT master reads the position values from the encoder. Mailbox communication on the application layer, process (input) data communication available. In SAFEOP only inputs are evaluated, outputs are kept in “safe” state.
OP	Operational, EtherCAT master reads the position values from the encoder in real-time. Process data inputs and outputs are valid.
BOOT	Bootstrap state. No process data communication. Communication only via mailbox on the application layer available. Special mailbox configuration is possible, e.g. larger mailbox size. In this state the File Access over EtherCAT [FoE] protocol is used for firmware download.

Table 3 EtherCAT state machine

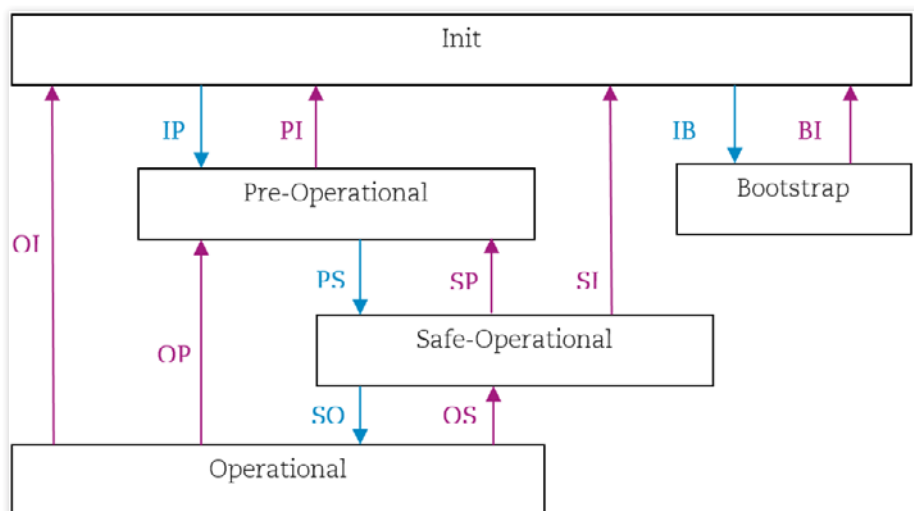


Figure 5 EtherCAT state machine

IP	Start mailbox communication
PI	Stop mailbox communication
PS	Start input update
SP	Stop input update
SO	Start output update
OS	Stop output update
OP	Stop output update
	Stop input update
SI	Stop input update
	Stop mailbox communication
OI	Stop output update
	Stop input update
	Stop mailbox communication

Table 4 Describes the EtherCAT state machine in figure 5

3.3 Operating parameters

Object 0x6000h, operating parameters, controls the functions for code sequence and scaling according to table 5.

Bit	Function	0	1
0	Code sequence for rotary encoder	CW	CCW
1	N.A.		
2	Scaling control	Disabled	Enabled

Bit	Function	0	1
3	N.A		
4	High-resolution scaling control	Disabled	Enabled

Table 5 Object 0x6000h Operating parameters

The code sequence defines whether increasing or decreasing position values are output when the encoder shaft rotates clockwise (CW) or counter clockwise (CCW) as seen on the shaft.

The scaling function control is used for enabling/disabling the scaling parameters: measuring units per revolution (object 0x6001h) and total measuring range in measuring units (object 0x6002h). If the scaling function bit is set, the scaling parameters will affect the output position value. If the scaling function bit is set to zero, the scaling function is disabled.

Enabling the high resolution (HR) scaling with bit 4 will instead enable the respective objects for high resolution scaling 0x6001h and 0x600Ah.

Example of how to set the operating parameters

To enable high resolution scaling and CCW operation, enable bit 0 and bit 4 in the operating parameters object by assigning 17 to 0x6000, ($2^0 + 2^4 = 17$).

Note: The position value will be affected when the code sequence is changed during operation.

It might be necessary to perform a pre-set after the code sequence has been changed.

Bit 2 and 4 are mutually exclusive, meaning they cannot be enabled at the same time.

3.4 Scaling function

The scaling function enables alteration of the numerical value converted in software to change the physical resolution of the encoder. The parameters “Measuring units per revolution” (object 0x6001h) and “Total measuring range in measuring units” (object 0x6002h) can subsequently be changed to achieve the desired resolution.

Object 0x600Ah sets the high resolution total measuring range.

Note:

Total measuring range in units = Measuring units per revolution x Number of distinguishable revolutions

When scaling a multi-turn encoder the parameter “Measuring units per revolution” must be set before the parameter “Total measuring range in measuring units”.

The data type for both scaling parameters is unsigned 32 with a value range from 1 to 2^{32} limited by the encoder resolution. For a 31 bit multi-turn encoder with a single-turn resolution of 19 bits the permissible value for the “Measuring units per revolution” is between 1 and 2^{19} (524 288). The permissible value for the “Total measuring range in measuring units” is between 1 and 2^{31} (2 147 483 648). To achieve the highest permissible value of 2^{31} (2 147 483 648) for the “Total measuring range in measuring units” the “Measuring units per revolution” must be set to 2^{19} . For high resolution encoders the total measuring range in measuring units is between 1 and 2^{63} . The scaling parameters are securely stored in case of voltage breakdown and reloaded at each start-up.

Object 0x6001h Measuring units per revolution

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

Table 6 Single-turn scaling parameter format

Default setting: 524 288 (19 bit)

Object 0x6002h Total measuring unit range

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

Table 7 Multi-turn parameter format

Object 0x600Ah High resolution Total measuring unit range

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
$2^7 - 2^0$	$2^{15} - 2^8$	$2^{23} - 2^{16}$	$2^{31} - 2^{24}$	$2^{39} - 2^{32}$	$2^{47} - 2^{40}$	$2^{55} - 2^{48}$	$2^{63} - 2^{56}$

Table 8 High resolution multi-turn parameter format

Note! A preset must be done after a scaling has been performed to ensure that the encoder position value is within the working range.

3.4.1 Scaling formulas

In the following formula a 31 bit multi-turn encoder with a single-turn resolution of 19 bit is used as an example.

$$A = \frac{(\text{singleturn_position} \times \text{measuring_units_per_revolution})}{524\,288}$$

$$\text{Output_position} = (\text{revolution_number} \times \text{measuring_units_per_revolution}) + A$$

Where: **singleturn_position** = the Absolute single-turn position value

revolution_number = the Absolute multi-turn number

3.5 Cyclic scaling

Cyclic operation, binary scaling, is used when operating with 2^x number of turns (2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048 and 4096 for SR encoder and up to 2^{16} for HR encoder). If the desired measuring range is equal to the specified single-turn resolution * 2^x (where $x \leq 12$ for SR encoder and $x \leq 16$ for HR encoder) the encoder operates in endless cyclic operation (0-max-0-max...).

For example, if the position value increases above the maximum value by rotating the encoder shaft, the encoder starts over from 0.

Example of cyclic scaling:

Measuring unit per revolution: 1000

Total measuring range = 1000×32 (2^5 = number of revolutions 32)

The position varies between 0 and 31999

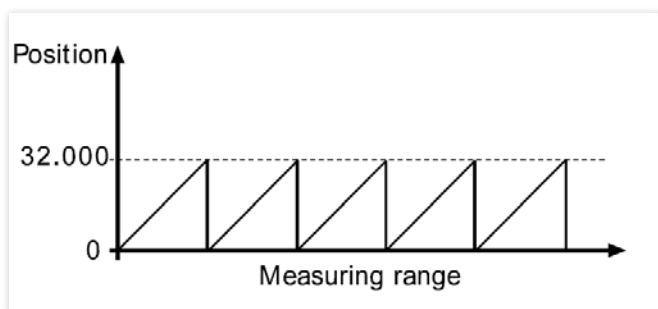


Figure 6 Cyclic scaling

3.6 Non-cyclic scaling

If the measuring range is used to limit the encoder value range to a value not equal to the specified single-turn resolution * 2^x, the output position value is limited within the operating range. If the position value increases or decreases outside the measuring range by rotating the encoder shaft beyond the maximum value or below 0, the device outputs the total measuring range value.

Example of non-cyclic scaling:

Measuring units per revolution = 100

Total measuring range = 50 x 100 (number of revolutions 50)

The position varies between 0 and 4999

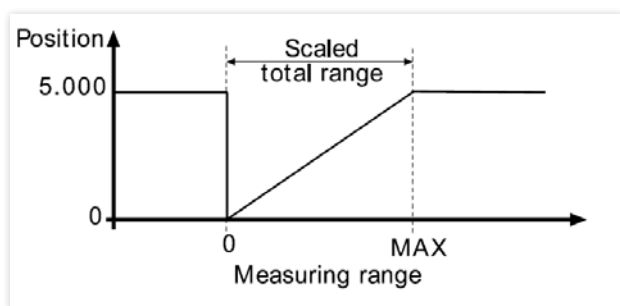


Figure 7 Non-cyclic scaling

3.7 Position value

Object 0x6004h contains the current encoder position value and may be scaled in accordance with the scaling factor.

Object 0x6004h

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

Table 9 Position value format

High resolution Position value

Object 0x6008h contains the current encoder position value and may be scaled in accordance with the scaling factor.

Note! Object 0x6008h is only valid for encoders > 32 bit resolution.

Object 0x6008h

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
$2^7 - 2^0$	$2^{15} - 2^8$	$2^{23} - 2^{16}$	$2^{31} - 2^{24}$	$2^{39} - 2^{32}$	$2^{47} - 2^{40}$	$2^{55} - 2^{48}$	$2^{63} - 2^{56}$

Table 10 HR position value format

3.8 Speed value

0x6030h Speed value

Object 0x6030h provides the output speed value in either RPM or multiplies of 1 ms for standard resolution encoders (32 bit) and for high resolution encoders (64 bit). The parameters for the speed value are set in object 0x6031h - Speed parameters, or 0x5003h – Speed type.

The calculated speed of the encoder is transmitted as a 16 bit value.

Byte 0	Byte 1
$2^7 - 2^0$	$2^{15} - 2^8$

Table 11 Speed value format

Either objects 0x5003h (Speed type) and 6031h (Speed parameters) or 6041h (Acceleration parameters) are to be used, not a combination.

- Writing to object 0x5003h disables object 0x6031h and 0x6041h.
- Writing to object 0x6031h or 0x6041h disables object 0x5003h.

The default setting is:

- Object 0x5003h value = 0.
- Objects 0x6031h and 0x6041h disabled.

Object 0x5003h Speed type

Object 0x5003h sets the integration time and resolution (steps/second or RPM) of the speed information. The object affects both the speed (object 0x6030h) and the acceleration (object 0x6040h). below describes the supported values.

Value	Speed/acceleration integration time	Speed unit	Acceleration unit
0	200 ms	Steps/s	Steps/s ²
1	10 ms	Steps/10 ms	Steps/(10 ms) ²
2	100 ms	Steps/100 ms	Steps/(100 ms) ²
3	200 ms	RPM	Rotations/min ²

Table 12 Speed resolution setting

The speed object is limited to a signed 16-bit value. In order to avoid data overflow and optimize the accuracy it is recommended to calculate the optimal speed type setting. Also, adapting scaling to the encoder will limit the amount of data which in turn helps avoiding overflow as the speed value calculation is based on the scaled single-turn value.

For example if the rotation of the shaft is faster than 1000 rpm and the speed type is 0, (option steps/s), a data overflow will occur. In this case a shorter integration time is required, i.e. steps/100ms.

Object 0x6031h Speed parameters

This object indicates the configuration of the parameters used for speed calculation. There are 4 sub-indices:

Sub-index	Definition
01h	Provides information regarding the position value used for speed calculations, refer to table 16.
02h	Provides speed integration time and is presented in multiples of 1 ms.
03h	Provides multiplier value.
04h	Provides the division value.

Table 13 Sub-index for speed parameters

The quotient of sub-index 03h and sub-index 04h provides the scaling factor for the speed value.

Value	Definition
00h	Reserved
01h	Object 0x6004h (position value) is used
02h	Object 0x600Ch (raw position value) is used

Value	Definition
03h	Object 0x6008h (high-resolution position value) is used
04h	Object 0x600Bh (high-resolution raw position value) is used

Table 14 Value definition for sub-index 01h

The speed is calculated according to the formula below:

$$v = \frac{dX}{dt} = \frac{X_{new} - X_{old}}{T_{integration}} \times \frac{C1}{C2}$$

Where

v	Speed value
dX/dt	First time derivative of the position X
X _{new}	New position value
X _{old}	Old position value
T _{integration}	Integration time in ms
C1	Multiplier constant
C2	Divider constant

The accuracy of the speed measurement is dependent on the chosen resolution. In figure 7 a 19-bit single-turn resolution is used for the calculations.

The table shows different shaft rotation speeds, and how the accuracy of the measured value deviates. In general, no matter which speed type is chosen, the accuracy will improve with higher shaft rotation speeds.

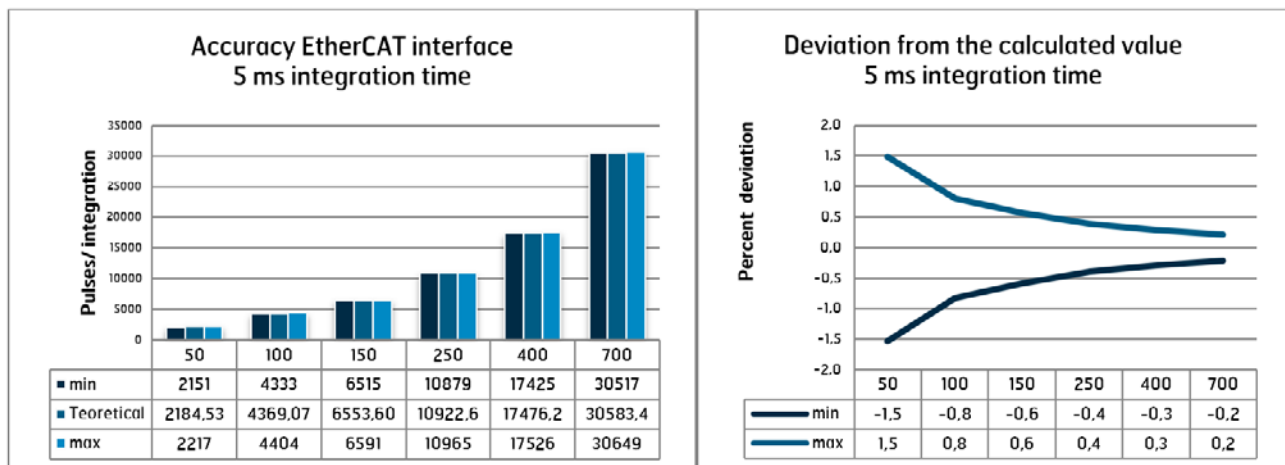


Figure 8 Accuracy of speed measurement

3.9 Acceleration value

Object 0x6040h Acceleration value

Object 0x6040h provides the output acceleration value. The acceleration value for standard resolution encoders (32 bit) and for high resolution encoders (64 bit) is given in multiples of measuring units per second. The acceleration parameters for the acceleration value are set in the object 0x6041h, Acceleration parameters.

The current calculated acceleration of the encoder is transmitted as a 16 bit value.

Byte 0	Byte 1
$2^7 - 2^0$	$2^{15} - 2^8$

Table 15 Acceleration value format

Object 0x6041h Acceleration parameters

Object 0x6041h indicates the configuration of the parameters used for calculating the acceleration. The object has 4 sub-indexes:

Sub-index	Definition
01h	Provides information regarding the position value used for calculating the acceleration, refer to table 19.
02h	Provides acceleration integration time and is presented in multiples of 1 ms.
03h	Provides multiplier value.
04h	Provides division value.

Table 16 Sub-index for acceleration parameters

The quotient of sub-index 03h and sub-index 04h, the multiplier and divider values, provide the scaling factor for acceleration value.

Value	Definition
00h	Reserved
01h	Object 0x6004h (position value) is used
02h	Object 0x600Ch (raw position value) is used
03h	Object 0x6008h (high-resolution position value) is used
04h	Object 0x600Bh (high-resolution raw position value) is used

Table 17 Value definition for sub-index 01h

The acceleration is calculated according to the formula below:

$$a = \frac{d^2X}{dt^2} = \frac{X_{new} - X_{old}}{T_{integration}^2} \times \frac{C1}{C2}$$

Where

a	Acceleration value
d^2X/dt^2	Second time derivative of the position X
X_{new}	New position value
X_{old}	Old position value
$T_{integration}$	Integration time in ms
C1	Multiplier constant

3.10 PDO mapping

In order to use the high-speed data exchange, fixed PDO (Process Data Objects) mapping is required.

The mapping alternatives are:

- **Fixed PDO**

- Fastest alternative
- Fixed process data
- Readable via CoE

- **Configurable PDO**

- CoE is required
- Writable PDO content

Note: Process data is only available when the encoder is in safe or operational mode.

TxPDO mapping times

TxPDO	Data transfer time [μs]	DC mode minimum cycle time [μs] (see note 1)
1A00 Default configuration	72	100
1A00 8 64 bit data values	83	100
1A20	8	Down to 31.25
1A21	8	Down to 31.25
1A22	8	Down to 31.25
1A40	8	Down to 31.25
1A41	8	Down to 31.25
1A42	8	Down to 31.25

Table 18 Mapping times for the PDO's

The values in table 20 are determined from the time required for the EnDat transfer, data calculation, data transfer, and process management inside the EtherCAT slave. It does not take into account the jitter on the Ethernet data transfer. Jitter is the time deviation from an assumed to be synchronized task, in this case node data transfer. Excessive jitter may result in synchronization errors even on much longer cycle times.

The cycle time value of the active PDO can be read from object 0x1C33:5h.

3.11 Configurable PDO

The following default mapping is set in the encoder when it leaves Leine Linde manufacturing. These parameters can be modified, exchanged or deleted. Up to eight (8) different objects can be used in Configurable PDO. The following objects are default at delivery:

- Position value
- Error register
- Alarms
- Warnings
- Time stamp [ms]
- Speed value
- Acceleration value
- Encoder temperature [0.1K]

3.12 Fixed PDO mapping

By using a fixed PDO the encoder can support a cycle time of down to 31.25 μs. These mappings are fixed and cannot be changed. The following fixed mapping alternatives are available:

- 1A2x for Fast Mapping of Standard Resolution (SR) Position Value (32-bit).
- 1A4x for Fast Mapping of High Resolution (HR) Position Value (64-bit).

Object .sub-Index	Object
1A20h	2nd TXPDO mapping
.0	Number of entries
.1	6004h Position value
.2	1001h Error register
.3	6503h Alarm status
.4	6505h Warning status
.5	2060h Time stamp [ms]

Table 19 Object 1A20

Object .sub-Index	Object
1A21h	3rd TXPDO mapping
.0	Number of entries
.1	6004h Position value
.2	1001h Error register
.3	6503h Alarm status
.4	6505h Warning status
.5	2060h Time stamp [ms]
.6	6030h Speed value

Table 20 Object 1A21

Object .sub-Index	Object
1A22h	4th TXPDO mapping
.0	Number of entries
.1	6004h Position value
.2	1001h Error register
.3	6503h Alarm status
.4	6505h Warning status
.5	2060h Time stamp [ms]
.6	6030h Speed value
.7	6040h Acceleration value

Table 21 Object 1A22

Object .sub-Index	Object
1A40h	5th TXPDO mapping
.0	Number of entries
.1	6008h High-resolution position value
.2	1001h Error register
.3	6503h Alarm status
.4	6505h Warning status
.5	2060h Time stamp [ms]

Table 22 Object 1A40 – 5th TXPDO

Object .sub-Index	Object
1A41h	6th TXPDO mapping
.0	Number of entries
.1	6008h High-resolution position value
.2	1001h Error register
.3	6503h Alarm status
.4	6505h Warning status
.5	2060h Time stamp [ms]
.6	6030 Speed value

Table 23 Object 1A41 – 6th TXPDO

Object .sub-Index	Object
1A42h	7th TXPDO mapping
.0	Number of entries
.1	6008h High-resolution position value
.2	1001h Error register
.3	6503h Alarm status
.4	6505h Warning status
.5	2060h Time stamp [ms]
.6	6030h Speed value
.7	6040h Acceleration value

Table 24 Object 1A42 – 7th TXPDO

4 Encoder diagnostics

4.1 Errors

Object 0x1001h Error register (16bits for encoders)

Bit	Description
0	Generic error (at least one bit has to be set from either this object or an alarm bit from object 0x6503h Alarms).
1	Current
2	Voltage
3	Temperature

Table 25 Error register

4.2 Alarms (16 bits)

Object 0x6503h Alarms

The following alarms are supported by the object:

Bit	Description
0	Position error
12	Single-turn error
13	Multi-turn error

Table 26 Alarms

4.3 Warnings (16 bits)

Object 0x6505h Warnings

Supported warnings

The following warnings are indicated by the object:

Bit	Value	Description
1	2	Light control reserve
4	16	Battery charge
6	64	Speed range
7	128	Acceleration range
12	4096	Temperature range

Bit	Value	Description
13	8192	Speed overflow
14	16384	Acceleration overflow

Table 27 Warnings

Object 0x2120h Speed range warning limit

To set Speed range, write maximum value to object 0x2120h:

Maximum value = 0x7FFF, 16-bit, ± 32768

A speed warning is set if the limit set is not 0. Do not exceed the maximum speed limit value stated in this manual.

If the speed range limit is exceeded a warning is sent in object 0x6505h.

Default value = 0

Byte 0	Byte 1
$2^7 - 2^0$	$2^{15} - 2^8$

Table 28 Speed range warning limit format

Object 0x2130h Acceleration range warning limit

To set Acceleration range, write maximum value to object 0x2130h:

Maximum value = 0x7FFF, 16-bit, ± 32768

An acceleration warning is set if the limit is not set to 0. Do not exceed the maximum acceleration limit value stated in this manual.

If the acceleration range limit is exceeded a warning is sent in object 0x6505h.

Default value = 0

Byte 0	Byte 1
$2^7 - 2^0$	$2^{15} - 2^8$

Table 29 Acceleration range warning limit format

Object 0x2110h Temperature warning limit

To set a temperature warning limit, write the maximum temperature value to object 0x2110h:

A temperature warning is set if limit is not 0. Do not exceed the maximum temperature limit value stated in this manual.

If the temperature limit is exceeded a warning is sent in 0x6505h.

Default value = 0

Byte 0	Byte 1
$2^7 - 2^0$	$2^{15} - 2^8$

Table 30 Temperature warning limit format

4.3.1 Overflow

An overflow warning is generated if speed (bit 13) or acceleration (bit 14) exceeds the maximum value respectively. These items have a maximum value of $\pm 32\,768$.

5 CANopen over EtherCAT (CoE)

This chapter describes which objects Leine Linde EtherCAT encoders support.

5.1 Object dictionary overview

The object dictionary structures the data of an EtherCAT device. It contains all device parameters and all current process data, these are therefore also accessible via the SDO.

Index	Object
0x0000-0x0FFF	Data type definitions
0x1000-0x1FFF	CoE communication profile range (CiA DS-301)
0x2000-0x5FFF	Manufacturer-specific profile range
0x6000-0x9FFF	Device profile range (CiA DS-406)
0xA000-0xFFFF	Reserved

Table 31 Object dictionary

5.1.1 Communication specific objects

ID	Name	Description
0x1C33:5	Minimum cycle time	Read out of cycle time for fixed PDO mapping: 1A20 1A21 1A22 1A40 1A41 1A42
0x2100	Encoder temperature [0.1K]	
0x2110	Encoder temperature warning [0.1K]	Default value = 0 A temperature warning is set if the limit set is not 0 and the maximum temperature limit value is exceeded.
0x2120	Speed range warning limit	Default = 0 Maximum value = 0x7FFF A speed warning is set if the limit set is not 0 and the maximum speed limit value is exceeded.
0x2130	Acceleration range warning limit	Default = 0 Maximum value = 0x7FFF An acceleration warning is set if the limit set is not 0 and the maximum acceleration limit value is exceeded.
0x5003	Speed type	Supported values: 0...3 Refer to chapter 3: Encoder functionality

Table 32 Describes the manufacturer-specific profile range

5.1.2 Device profile range

ID	Name	Description
0x6000	Operating parameters	Supported bits: Bit 0= Code sequence for rotary encoder Bit 2 or 4: Scaling function control for standard or high resolution encoders
0x6001	Measuring units per revolution	Only valid for rotary encoders
0x6002	Total measuring range in measuring units	
0x6003	Pre-set value	Enter value to pre-set
0x6004	Position value	
0x600C	Position raw value	
0x6008	High resolution position value (Only available for HR encoder)	
0x600B	High resolution position raw value (Only available for HR encoder)	
0x6009	High resolution pre-set value (Only available for HR encoder)	
0x600A	High resolution total measuring range in measuring units (Only available for HR encoder)	
0x6030	Speed value	
0x6031	Speed parameters	Refer to chapter 3 Encoder functionality
0x6040	Acceleration value	
0x6041	Acceleration parameters	Refer to chapter 3 Encoder functionality
0x6501	Single-turn resolution	- For rotary encoders the value corresponds to EnDat 2.1 parameter, word 20,21
0x6502	Multi-turn resolution (number of distinguishable resolutions)	The value corresponds to the appropriate EnDat 2.1/2.2 parameters (rotary encoders only)
0x6503	Alarms	Refer to chapter 5 Encoder diagnostics
0x6504	Supported alarms	Supported alarms bit description, refer to chapter 5 Encoder diagnostics
0x6505	Warnings	
0x6506	Supported warnings	Supported warnings bit description, refer to chapter 5 Encoder diagnostics
0x6507	Profile and software version	Bit 15:0 value = 0x0400 Bit 31:16 format = 0x1234

ID	Name	Description
0x6508	Operating time	Encoder operating time in multiples of 6 min
0x6509	Offset value	
0x650A	Module identification	
0x650B	Serial number	-The value corresponds to object 1018:4
0x650D	Absolute accuracy	-Default value = 0
0x650E	Device capability	-Value for standard resolution encoders = 0x0002 -Value for high resolution encoders = 0x000A
0x650F	High resolution offset value	
0x6510	High resolution number of distinguishable revolutions	The value corresponds to the appropriate EnDat 2.1/2.2 parameters (rotary encoders only)

Table 33 Describes the Device profile range (CiA DS-406)

6 Configuration example

The configuration example in this manual is based on TwinCAT manager developed by Beckhoff. If another configuration tool is being used please consult your tool supplier for more information.

6.1 Adding an I/O device by Scan

Ensure that you have changed your target system from <local> to your PLC and that you have installed the relevant ESI file in the ESI-directory.

Start a new project. In the Solution Explorer, right-click PLC and select "Add New Item...". Select for example Standard PLC Project. If needed, restart TwinCAT in Config Mode.

Start by adding an I/O device to your TwinCAT project.

Right-click on Devices under I/O and click Scan. When TwinCAT asks "Scan for boxes?", click Yes. When TwinCAT asks "Activate Free Run?", click Yes.

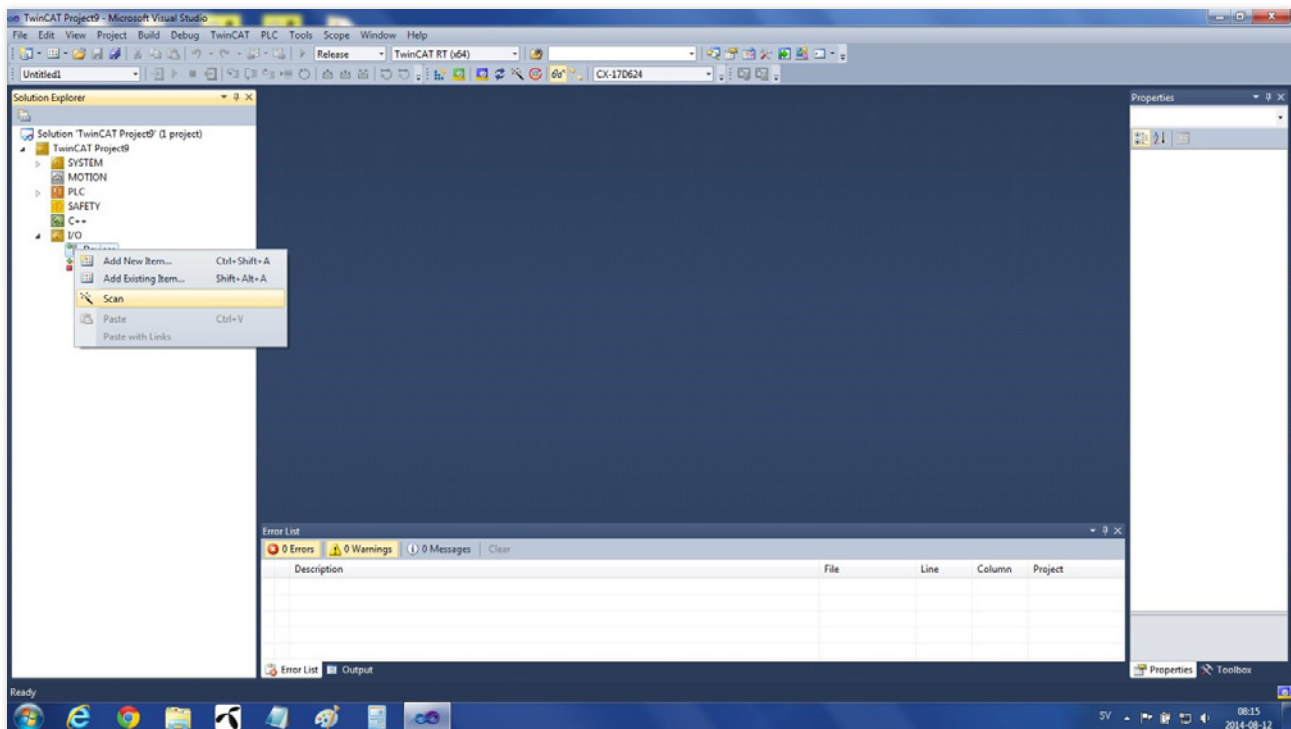


Figure 9 Adding I/O by scan

By scanning the EtherCAT device a Leine Linde encoder (box) will be found and added to the I/O, see figure 15 below.

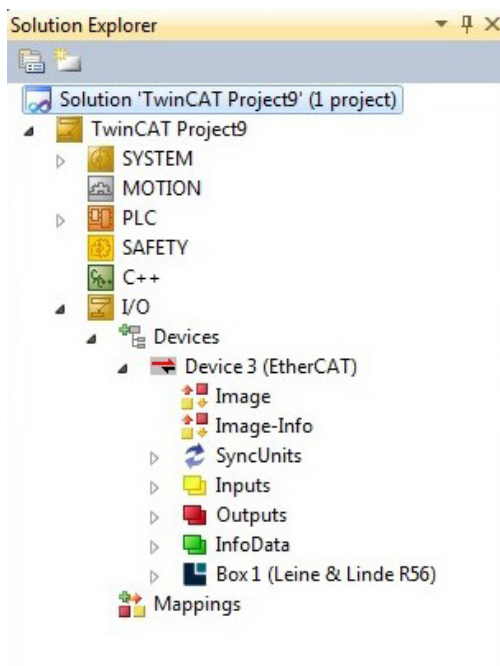


Figure 10 Added encoder to I/O

6.2 Adding an I/O device manually

In your TwinCAT project, you can manually add a box without having the physical encoder connected to the system.

- Right click on Devices
- Add New Item...
- Add EtherCAT master
- Add Leine Linde slave

Please consult the TwinCAT documentation for the further procedure

6.3 Setup PDO mapping

How to adjust the setting of Process Data Object based on TwinCAT software:

1. Select device to configure
2. Open Process Data tab
3. Select Inputs
4. Assign pre-mapped configuration. Deselect PDO and then assign new.

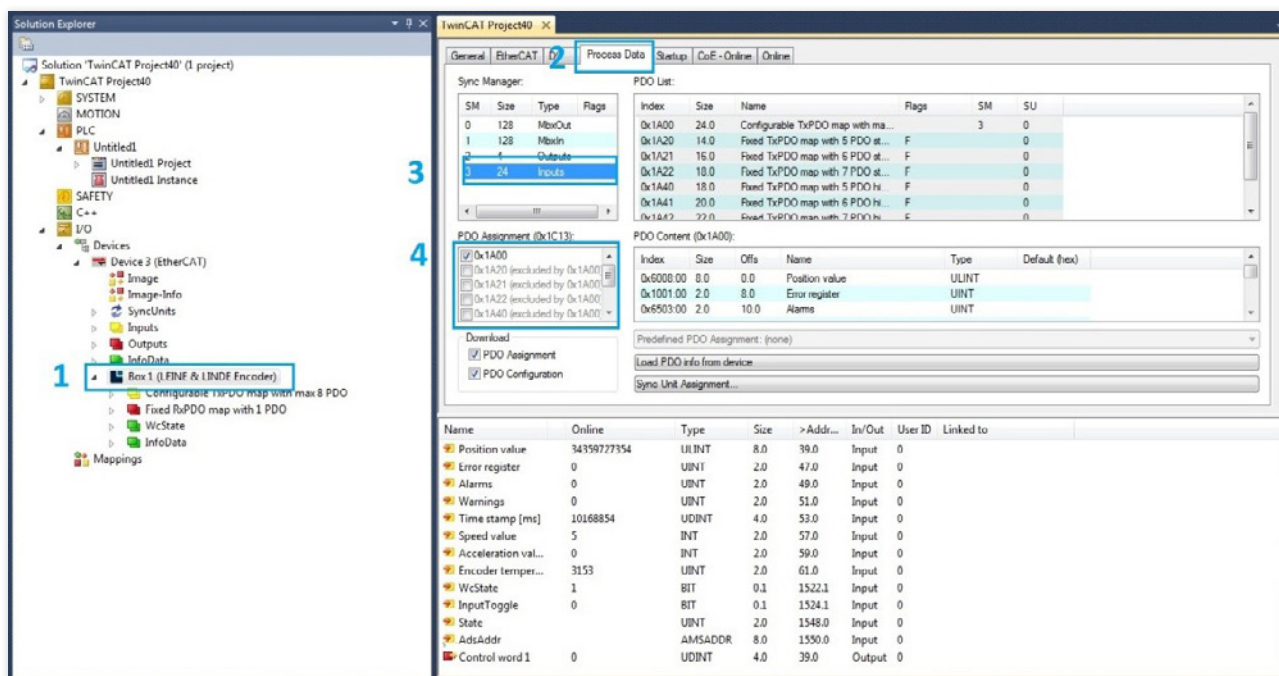


Figure 11 PDO mapping

Note: Only one PDO can be used at a time.

The new process data are visible as linkable variables in the system manager. This data is active once the configuration has been activated.

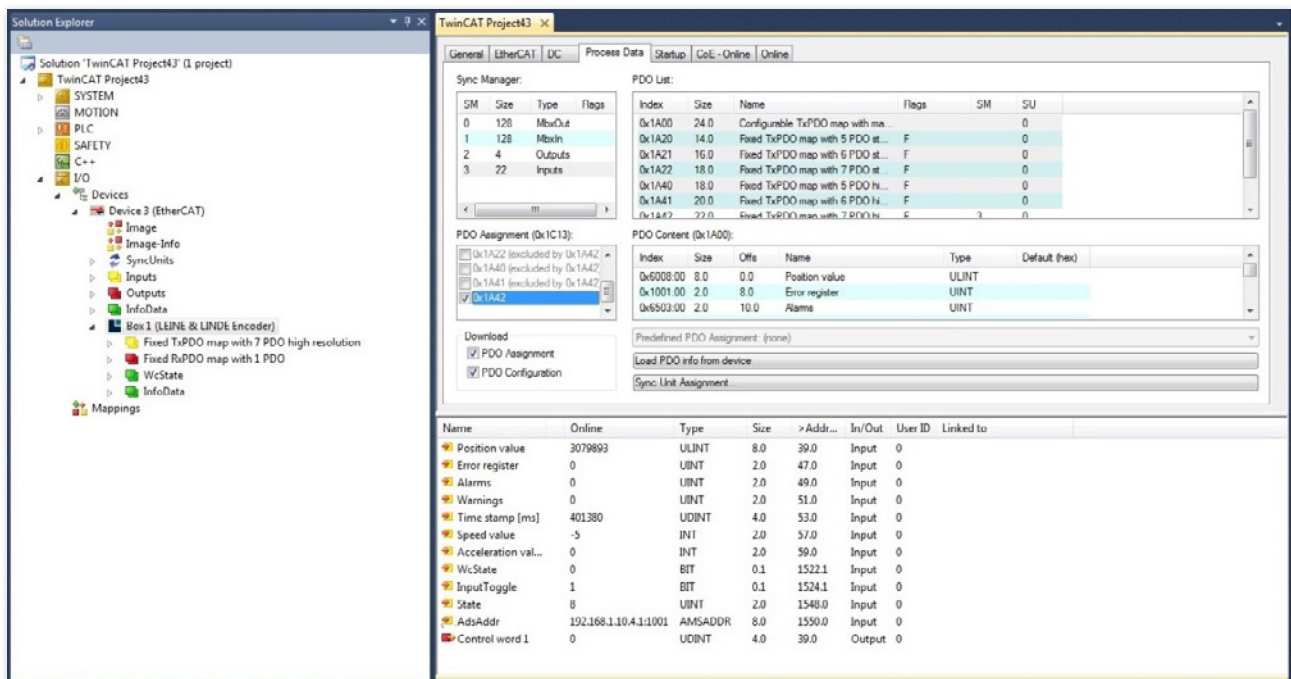


Figure 12 Linkable variables

Change configurable PDO.

1. Select device to configure.
2. Open Process Data tab and select 0x1A00 (configurable PDO) from the PDO list.
3. Right-click in PDO content.
4. Insert, edit or delete objects.

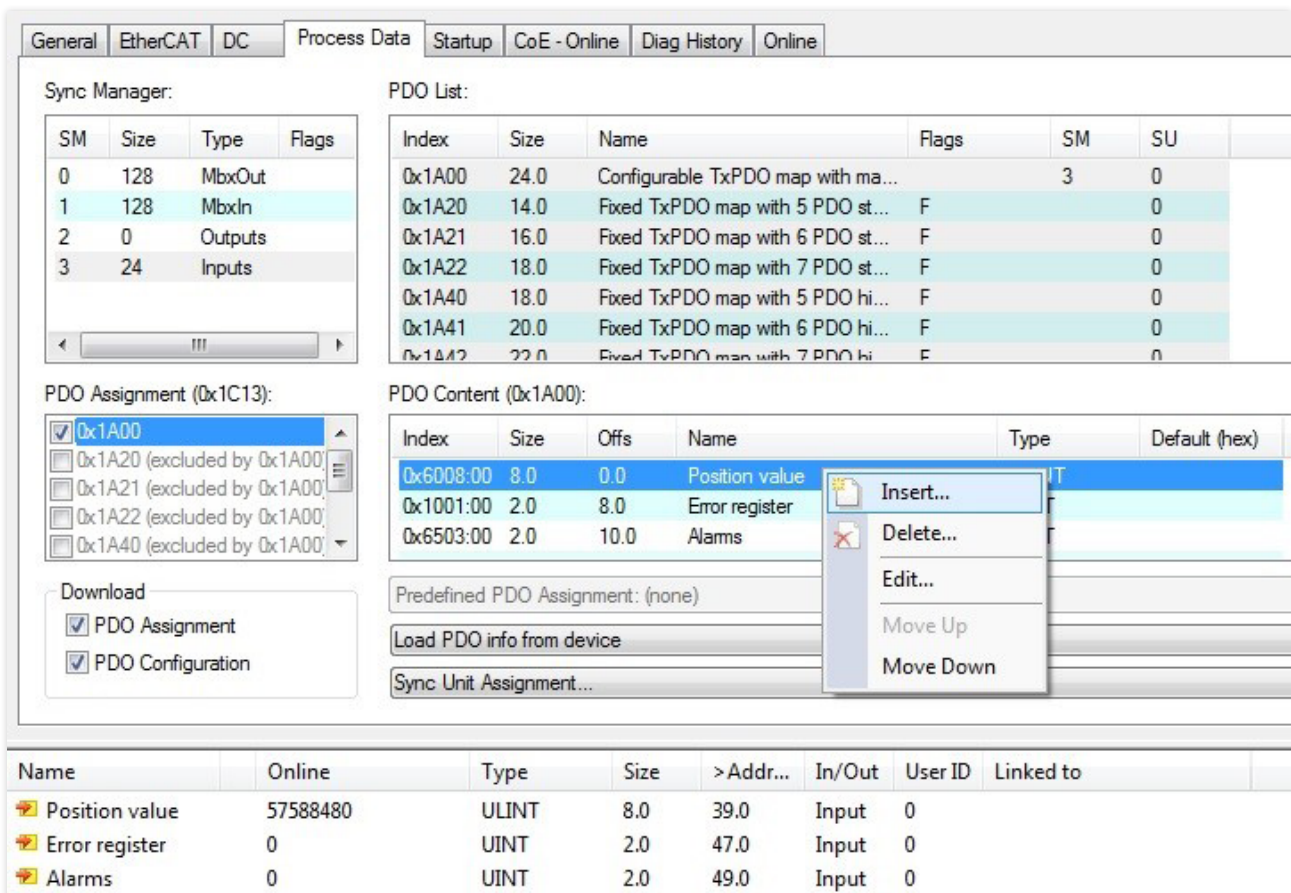


Figure 13 Change configurable PDO

7 Link PDO content to PLC project

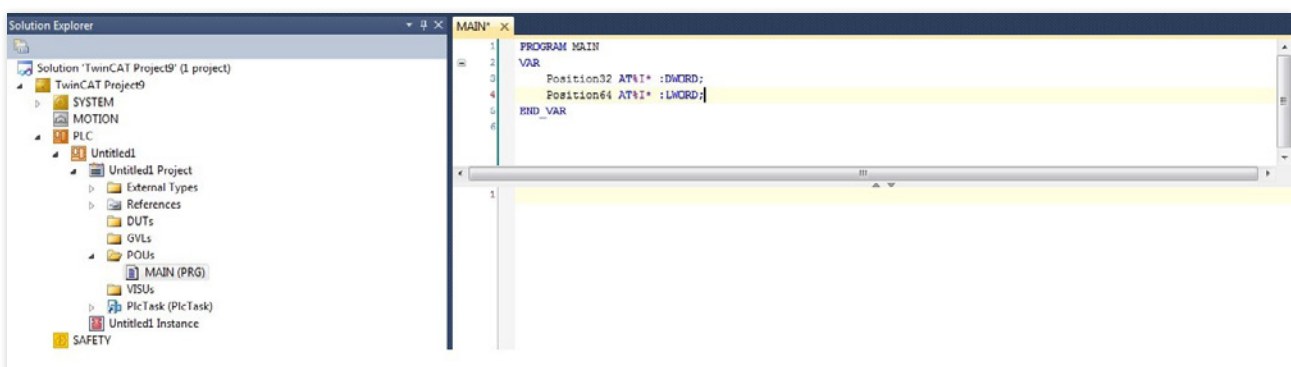


Figure 14 Link PDO to PLC project

Right-click "POU" Under PLC/Untitled1/untitled Project/ and add a POU, give it a name such as "MAIN" and select "program". In the created text document, add the variables you are interested in linking. In figure 14 variables Position32 and Position64 have been added together with a bit length identifier.

In order to link the variables, start "Activate Configuration" by clicking on the symbol:

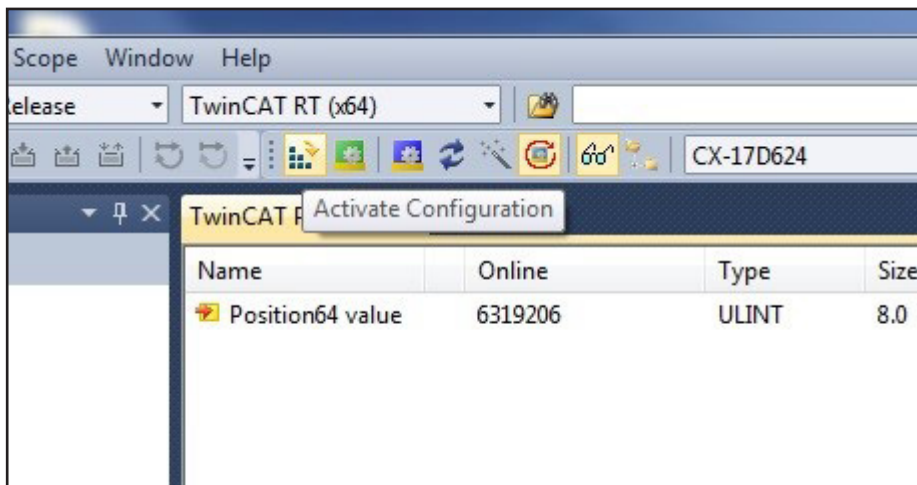


Figure 15 Activate configuration

When TwinCAT asks "Restart TwinCAT System in Run Mode?", click OK. In the I/O device, click on the Position value in order to link the variable written in your PLC projects main programming file, here called MAIN. See figure 16. Activate the configuration again, then restart in Run Mode

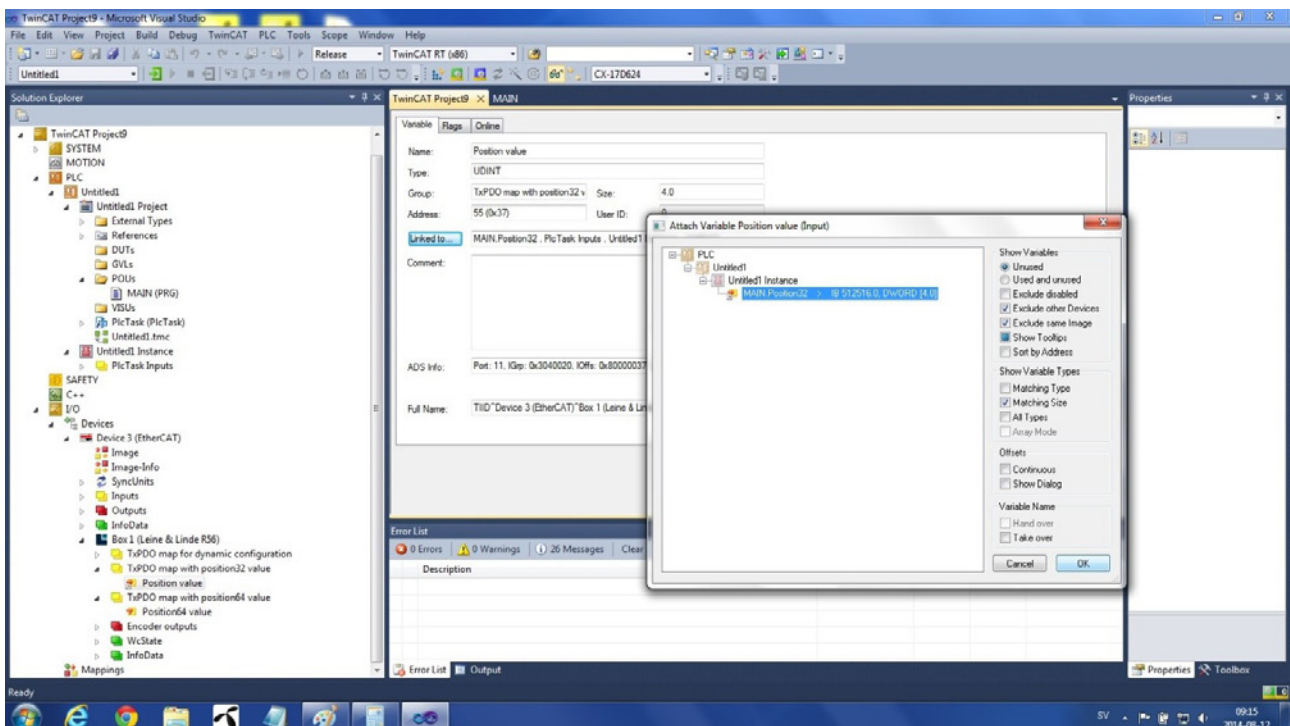


Figure 16 Attach variable to MAIN

7.1 Set up of Distributed clocks or Synchronization mode

Choose the required operating mode Distributed clock (DC) or Synchronization mode (SM) in your control system. If the encoder needs high accuracy for real-time applications DC mode should be used.

7.1.1 How to configure DC or SM

For DC or SM mode a special task has to be created inside the TwinCAT project. For this purpose the following steps have to be executed:

- Open context menu for SYSTEM / Tasks and select: Add New Item...
- Assign a name for the task (e.g. Task DC mode) and select: "TwinCAT Task With Image"

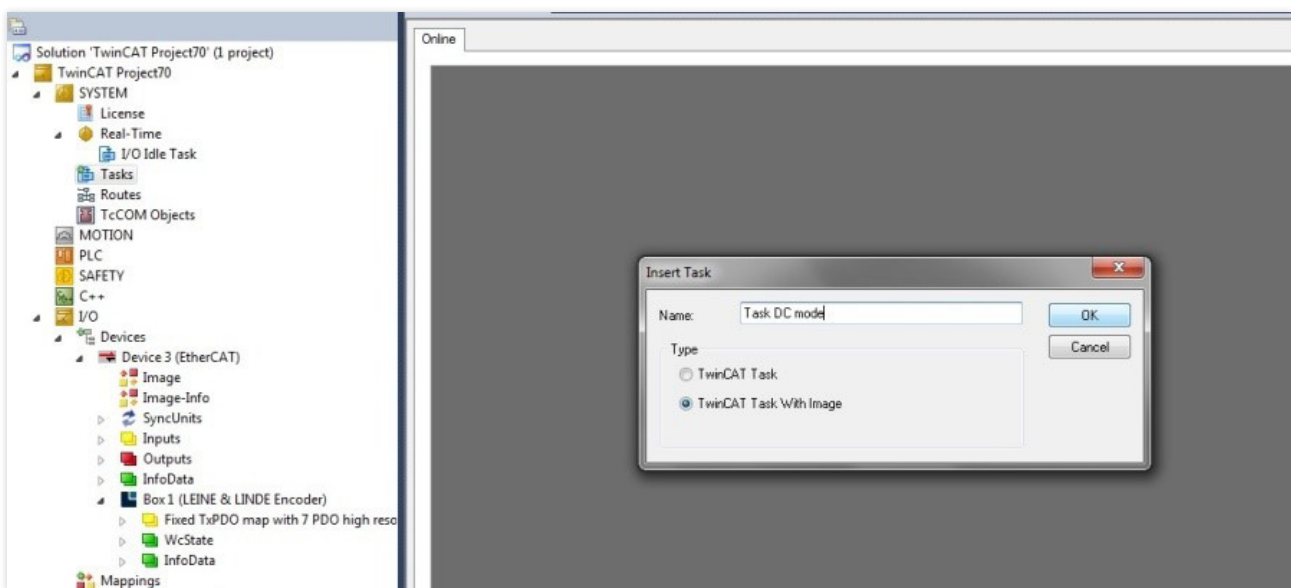


Figure 17 Configure DC or SM

Open context menu for SYSTEM / Tasks / Task DC mode / Inputs and select: Add New Item...

Assign a name for the variable (e.g. Var DC Pos64) and a type which corresponds to the type of an object in a currently used mapping (e.g. ULINT for a high resolution position value).

Activate SYSTEM / Tasks / Task DC mode / Inputs / Var DC Pos64

In the opened window activate Linked to... and select an object from the box (e.g. Position value).

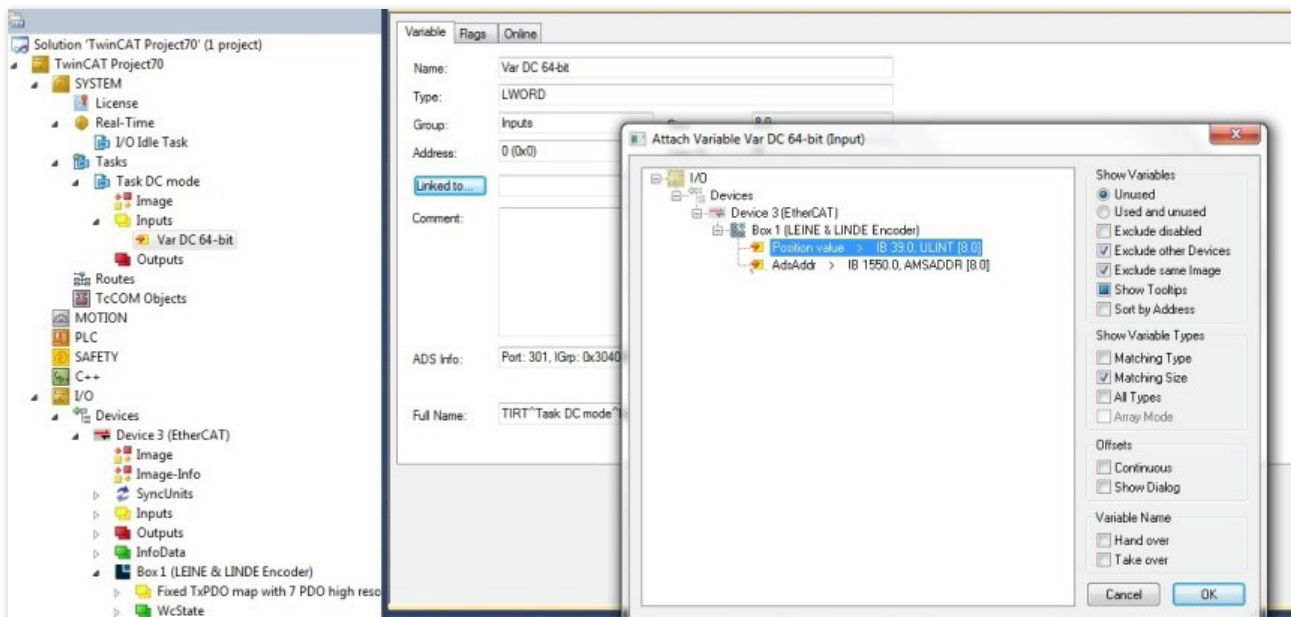


Figure 18 Attach variable

- Activate SYSTEM / Real-Time and select the “Settings” tab.
- Select the Base Time for CPU 0 (this is the shortest cycle time that can be selected).
- Activate SYSTEM / Tasks / Task DC mode and select the Task tab.
- Tick the “Auto start” box.
- Set Cycle ticks as a multiplier of the Base Time to set up the cycle time.
- Activate the current box under “I/O”/Devices/Device Name/ and select the “DC” tab.
- Select operation mode “DC-Synchron” or “SM-Synchron”.

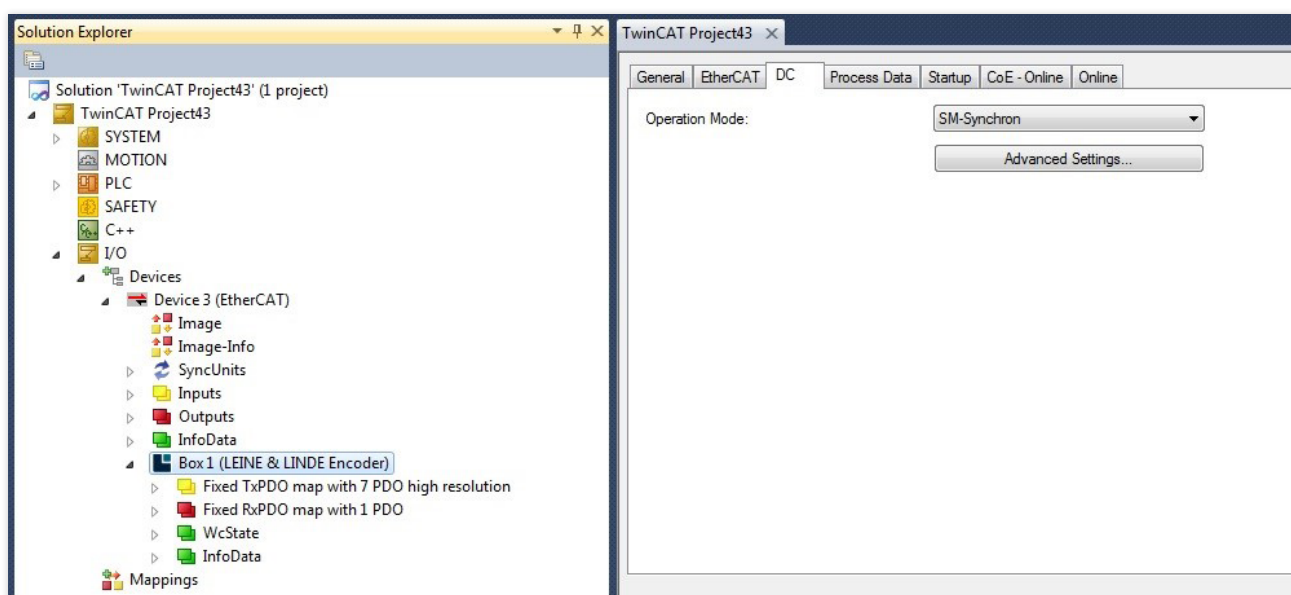


Figure 19 Select operation mode

- Execute TwinCAT / Activate Configuration

Synchronization mode selection

Free Run mode

- Execute TwinCAT / Restart TwinCAT (Config Mode)

SM-Synchron mode

- Activate the current box under “I/O”/Devices/Device Name/ and select the “DC” tab.
- Select operation mode SM-Synchron.
- Execute TwinCAT / Activate Configuration.

DC-Synchron mode

- Activate the current box under “I/O”/Devices/Device Name/ and select the “DC” tab.
- Select operation mode DC-Synchron.
- Execute TwinCAT / Activate Configuration.

Cycle time for Free Run

- Activate the current device and select the “Adapter” tab.
- Select Free run Cycle (ms).

Cycle time for DC or SM mode

- Activate SYSTEM / Real-Time and select the Settings tab.
- Select the Base Time for CPU 0 (this is the setting for the shortest cycle time that can be selected).
- Activate SYSTEM / Tasks / Task DC mode and select the Task tab.
- Set Cycle ticks to a multiple of the Base Time to set up the cycle time.
- Execute TwinCAT / Activate Configuration.

The encoder supports cycle times between 31.25µs and 32ms.

8 File over EtherCAT

File over EtherCAT (FoE) is a very simple protocol similar to TFTP, and enables access to any data structure in the device. Standardized firmware uploads to devices are therefore possible.

A firmware image for update has to be written to the encoder via FoE. From a TwinCAT Project, perform the following steps:

1. Activate tab “Online” of the appropriate box.
2. Activate button “Bootstrap”.
3. In the same Tab activate button “Download”.
4. In the opened File Open dialog select a firmware update image file.
5. In the opened “Edit FoE Name” dialog assign a name. The filename itself has no meaning.
6. The extension has to be “.llefww” to identify the file as an image file for update.
7. After the download has finished, and the image is valid, the update starts.

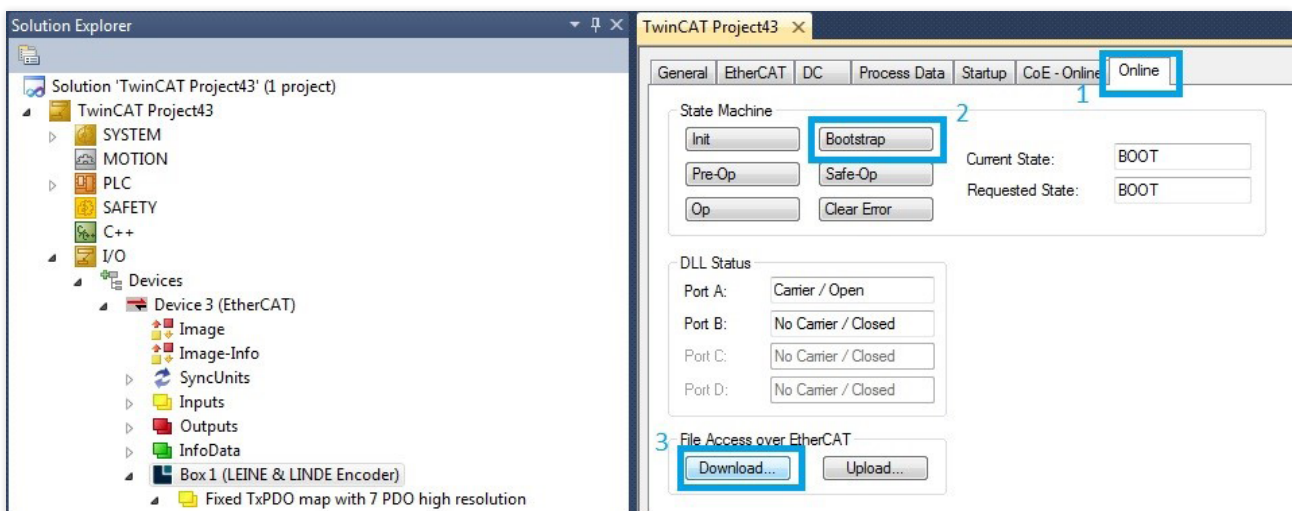


Figure 20 File over EtherCAT

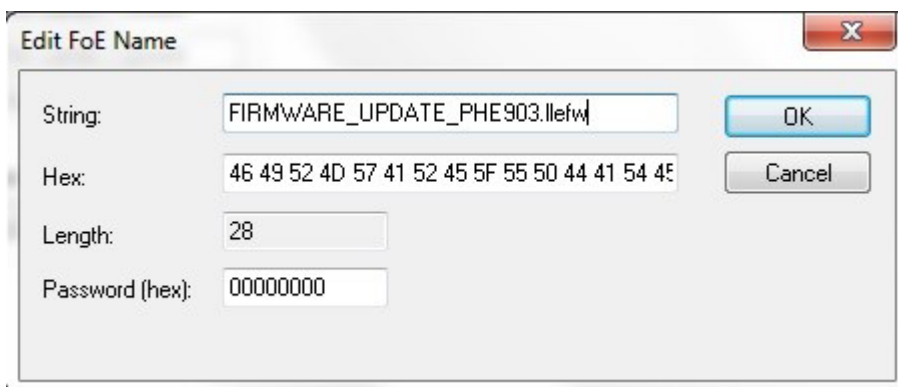


Figure 21 FoE name

9 Revision history

Revision	Date	Changes
Rev. 01	2017-01-18	First release
Rev. 02	2025-06-04	Corrections and clarifications

Table 34 Revision history



The best encoders are those you never have to think about. Those that simply do their job – year after year. Leine Linde develops and manufactures customised encoder solutions for demanding environments, advanced measuring systems for accurate feedback of speed and position.

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