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.Basics on position measuring systems, evaluation, resolution

.General information

.Position measurement options

Position encoders are used for measuring the actual values of the velocity and position control loops. Regarding drive control, there are the following position measurement options:

- At the motor only (position measurement via encoder 1/motor encoder)

- or -

- Both at the motor and at the drive mechanics (position measurement via encoder 1/motor encoder and encoder 2)

.Types of position measuring systems

Position measuring systems are available for the different kinds of motion in adapted types of construction and, with suitable signal specification or protocol specification, can be evaluated by ctrlX DRIVE controllers:

- Rotary encoders
- Linear encoders

Regarding the transmission of position data, there are three different classes of encoders:

- Digital encoders (only digital position information via serial data protocol)
- Combined encoders (position information via analog signals, additional digital position information via serial data protocol)
- Analog encoders (position information via analog signals, sin/cos (also modulated) or square-wave)

.Relevance for the user

.Use case

Information as decision-making support for selecting

- Encoder interface options of ctrlX Drive controllers
- motor encoder options of MS2x Rexroth motors
- types of required position encoders

Information on allowed combinations of position encoders and ctrlX Drive controllers

.Application-related information for project planning

.Precision, resolution

The precision of the position measurement depends on:

- the resolution of the position encoders e.g.:
  - division periods (DP)/revolution or µm/DP (linear encoders) for analog encoders
  - increments/revolution or increments per measuring distance (linear encoders) for digital encoders
- the absolute encoder precision that depends on the design and the quality of its components. The data for the absolute precision are specified by the manufacturer of the encoder.
- the digitalization quality of analog encoder signals: ctrlX DRIVE has a sine signal resolution of 2^18 increments/DP.

.Advantage of absolute evaluation

Absolute evaluation of position encoders means that the required travel range of an axis is smaller than or equal to the position value range (absolute encoder range) of an encoder that can be displayed in absolut form.

Absolute evaluation of encoder 1/motor encoder is particularly advantageous for the commutation of Rexroth kit motors and third-party motors (see "Commutation settings", ↘ “Application-related information for project planning”.

The absolute encoder range of rotary position encoders with "multi-turn" property is highly extended as compared to their single-turn value range!

.Advantage of encoder data memory

Automatic detection of connected encoders and configuration of their physical features in the case of:

- Motor encoders of Rexroth housing motors
- Encoders with ACURO®link interface
- Encoders with ctrlX SENSE^{motor} interface
- Encoders with EnDat2.2 interface
- Encoders with HIPERFACE® interface

Resolver encoders and SSI encoders require manual configuration!

.Use case encoder type selection

Conventional position encoders that can be evaluated (AXS-V-03RS):

- Motor encoders of MS2x motors:
  - Encoder performance with ACURO®link via standard connection XG20
  - Encoder performance with HIPERFACE® via optional connection XG21
- ACURO®link encoders (digital encoders) via standard connection XG20
- HIPERFACE® encoders (combined encoders) via optional connection XG21
- Resolver encoders (analog encoders) via optional connection XG21
- SSI encoders (digital encoders) via standard connection XG21

.Use case encoder connection

Per axis, the controller provides a maximum of two interfaces for connecting the position encoders. Using the type code, the controller has to be selected in such a way that each axis has the required encoder interfaces (see ctrlX DRIVE

Project Planning Manual)

Example of a double-axis XMD controller:

.Selecting encoder interface options of the controller

Axis	Interface	Note
1	XG20.1	Standard: Digital motor encoder connection
1	XG21.1	Option: EC, multi-encoder interface connection
2	XG20.2	Standard: Digital motor encoder connection
2	XG21.2	Option: EC, multi-encoder interface connection

See also documentation (DOK-XDRV**-X**********-PRxx-EN-P; mat. no. R911386579)

Evaluating position encoder reference marks

- Virtual reference marks can be used:
  - Resolver:
    a virtual reference mark at the pole pair "zero point" per resolver pole pair
  - HIPERFACE® encoder:
    a virtual reference mark at the "zero point" of the single-turn angle range of rotary encoders
- With AXS-V-0304 it is not yet possible to use real reference marks of position encoders!

.Options of functional use of encoders (ENCE)

On the firmware side, there are the following options for functional use of encoders:

.Overview of the evaluation options of encoders, depending on ctrlX DRIVE controller

ctrlX DRIVE	XCS, XMS	XMD, XMQ
Firmware	AXS	
Motor with motor encoder (FOC operation)	G1 G1, G2	G1 G1, G2 (per axis)

ctrlX DRIVE	XCS, XMS	XMD, XMQ
Sensorless motor (SVC operation)	G2	G2 (per axis)

Legend:

G1:*Encoder 1/motor encoder*

G2:*Encoder 2*

.Commissioning

.Dialog-supported configuration

With "ctrlX DRIVE Engineering", the settings relevant for the position measuring system can selected in a dialog-supported form:

- Selection or assignment of the interface (optional slot) for encoder function (motor encoder or optional position control encoder)
- Selection or assignment of the encoder used

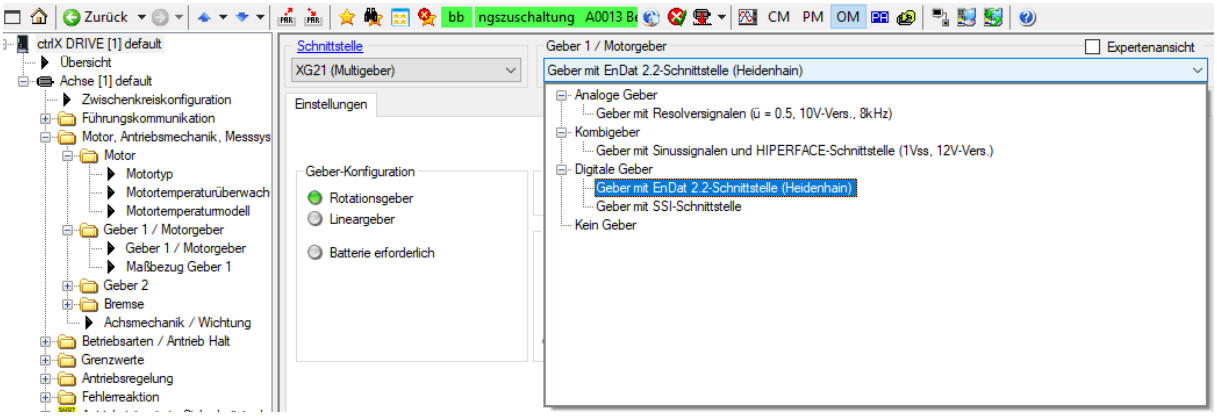

Fig. 169: ctrlX DRIVE Engineering basic dialog for encoder function "Encoder 1/motor encoder": Interface selection and selection of the encoder type

- Configuration of encoder properties and features
  The dialog also shows whether absolute encoder evaluation is possible with the selected travel range and the existing encoder configuration:

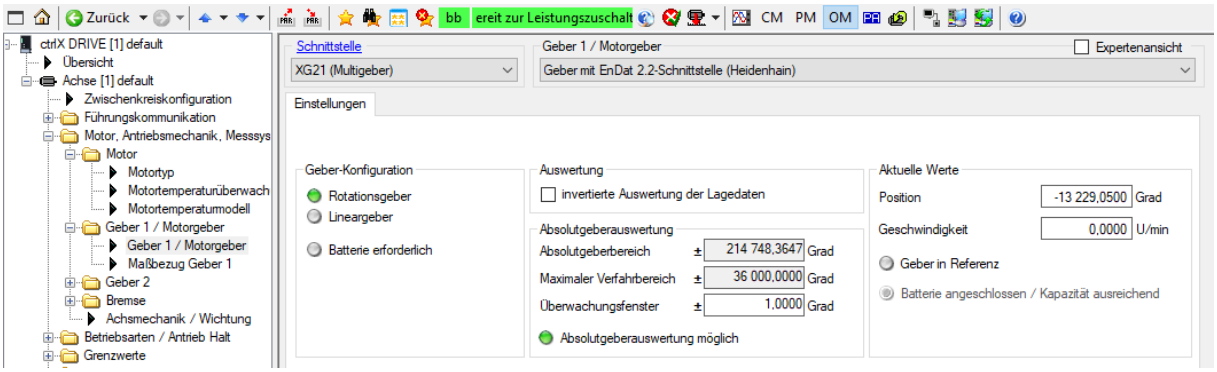

Fig. 170: ctrlX DRIVE Engineering basic dialog for encoder configuration: Settings and current values

If required, in-depth details of the encoder configuration and evaluation can also be displayed by a dedicated extended dialog ("Expert view") for additional settings for absolute encoder configuration:

- In addition to "Inverted position data evaluation" (selectable also in Basic view of the "Settings" encoder dialog), "Inversion of rotational direction" (selectable only in "Expert view") is also possible. Both inversions neutralize each other. (In the case of multiple evaluation of an encoder, neutralization of an inversion due to mounting may be beneficial).
- The absolute encoder evaluation can be deactivated or forced. Both are only relevant in special cases. See ↘ “Forcing absolute evaluation” .
- With encoders to be evaluated in absolute form, "drive-controlled homing" is also possible in "AF". However, this option has to be enabled (this generally applies to all encoder types). See also Fig. 171 and .

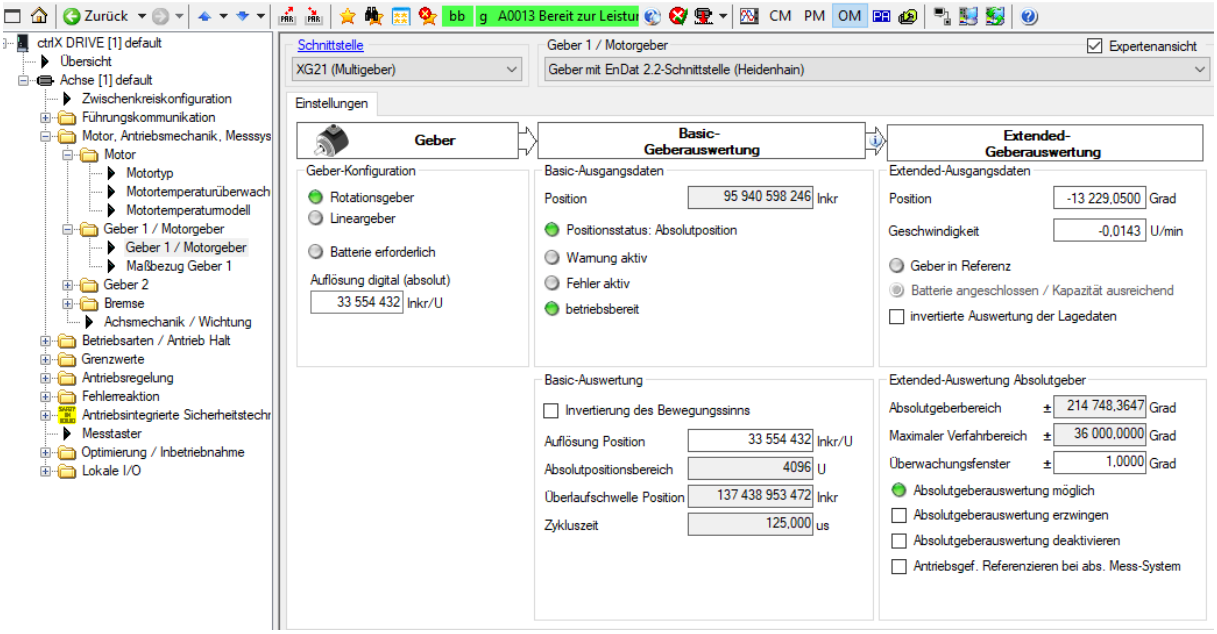

Fig. 171: Display of the "Expert view" of the ctrlX DRIVE Engineering encoder dialog for extended configuration and information options

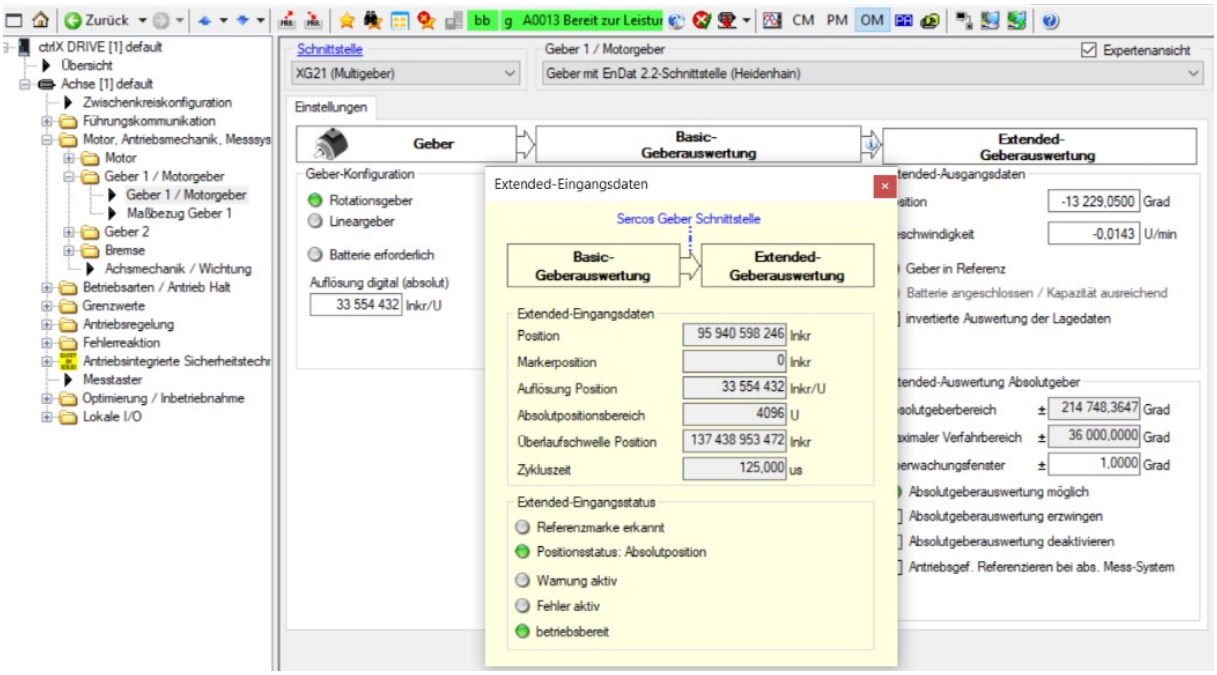

Fig. 172: Visualization of the input data of function-related extended encoder evaluation in "Expert view" of the ctrlX DRIVE Engineering encoder dialog

For Rexroth housing motors with motor encoder data memory, the basic encoder configuration settings are automatically made!

.Additional information and details

.Control loops and position measuring

Operating drives in the closed control loop requires position measuring systems in order to metrologically acquire the current state of the physical value to be controlled, the so-called actual value.

We distinguish the following drive control loops:

- Torque/force control loop
  → Actual value by evaluating the current measuring system and converting the value
- Velocity control loop
  → Actual value by evaluating the position measurement system and time-derivation
- Position control loop
  → Actual value by evaluating the position measurement system

.Two-step encoder evaluation

The signals or information of a connected encoder are provided by Basic evaluation ("ENCoderBasic") in a standardized format (SIII Encoder Profile) and converted to a scaled position via an extended function-specific evaluation

("ENCoderExtended" "Encoder 1/motor encoder" or "Encoder 2"). The position evaluation for all encoder functions takes place in an interval of 125 µs (velocity controller clock).

- Step 1, Basic encoder evaluation:
  Generating the unscaled original encoder position (S-0-0600.x.21 and S-0-0600.x.22)
- Step 2, Extended encoder evaluation:
  Generating scaled positions for display and axis control (Sercos position scaling format or incremental position scaling format).

For axis control, a position is generated in a high-resolution, scaled position format.

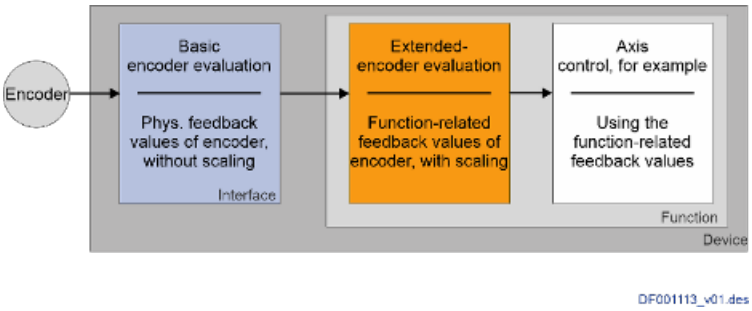

Fig. 173: Principle of encoder evaluation according to Sercos III encoder profile

.Basic encoder evaluation

Using the Basic encoder evaluation (ENCB), the position information of a physical encoder is converted to the standardized **SIII Encoder Profile**. The evaluation is related to the encoder interface or the encoder slot.

The Basic encoder evaluation provides the following data regarding the connected encoder:

- Physical actual position, encoder-based
- Position resolution
- Encoder status, error codes
- Absolute position range
- Overflow threshold for position values
- Cycle time for encoder output data

The Basic encoder evaluation has to be informed of the physical data of the connected encoder:

- Physical encoder type
- Physical encoder properties, like rotary encoder or linear encoder
- Physical encoder resolution, analog and/or digital
- Where applicable, transmission protocol configuration in the case of a digital encoder

.Extended encoder evaluation

Encoder-related actual position values and status data from a Basic encoder evaluation (ENCB) in the "SIII Encoder Profile" can be evaluated by Extended encoder evaluation (ENCE) in relation to the motor or axis mechanics.

- Motor or load reference

- Rotary or linear scaling (mapping of motor - load mechanical transmission) or incremental scaling

For Extended encoder evaluation, the following functions can be applied:

- Motor encoder (encoder 1)
- Position control encoder (encoder 2, but also encoder 1)

.ENCB - ENCE parameter structure

For the parameters of the ENCB and ENCE evaluation, an "instanced" parameter structure is used: S-0-####.x.y

.ENCB configuration and ENCB output data, as well as ENCE input data, parameter structure

Encoder evaluation	Basic output data (ENCB)	=>	Extended input data (ENCE)
Current data, actual values	S-0-0600.x.y	=>	S-0-0610.x.y
Output data configuration	S-0-0601.x.y	=>	S-0-0611.x.y
Physical encoder configuration	S-0-0602.x.y		
Instanced parameters S-0-????.x.y: "x": structure instance index; "y": structure element number			
	"x" with ENCB is the number of the device interface or the slot at which the position encoder has been connected.		"x" with ENCE is the number of function assignment 1: Encoder 1/motor encoder 2: Encoder 2:
Legend: **ENCB:** Encoder Basic evaluation (interface- or slot-related) **ENCE:** Encoder extended evaluation (function-related: motor encoder, position control encoder (encoder 2) or measuring encoder)			

The identification numbers (IDN) of the ENCE input data are very similar to the numbers of ENCB output data. The difference is mostly the tens digit of the identification number!

.Structure instance with Basic output data (ENCB)

The "Basic" evaluation (ENCB) refers to the interface the encoder has been connected to or the encoder cable connector has been plugged in (slot reference, optional fitting with multi-encoder input, where applicable, required):

.Encoder interfaces and related values of the ENCB parameter structure instance x

Axis no. / encoder interface	XMS, XCS controllers	XMD, XCD controllers	Structure instance x with ENCB param.
1 / onboard	XG20	XG20.1	10
1 / option 2	XG21	XG21.1	2
2 / onboard	-	XG20.2	10
2 / option 2	-	XG21.2	2

.Structure instance with Extended input data (ENCE)

The "Extended evaluation" (ENCE) uses the standardized encoder information provided by the Basic evaluation for the actual encoder function:

.ENCE functions, designations and related values of ENCE parameter structure instance x

Function (ENCE)	Designation in the parameter structure	Structure instance "x" with ENCE param.
Motor / position control encoder	Encoder 1	1
Position control encoder	Encoder 2	2

.Encoder assignment for Extended evaluation

Via the following parameters, the encoder-related Basic evaluation is assigned to the function-related Extended evaluation:

.Function assignment to the connected encoder

Function	Parameters for the interface assingment of the connected position encoders:
Encoder 1/motor encoder	P-0-0077
Encoder 2	P-0-0078

With the mentioned parameters, the interface is selected. The Basic evaluation of the interface provides the standardized position encoder information for the respective function.

.Physical encoder resolution

Depending on the encoder class used, the physical encoder resolution is entered in the following parameters or set automatically for encoders with encoder data memory:

- Analog encoders
  The physical encoder resolution is specified with relation to division periods (DP) in "S-0-0602.x.21, Phys. encoder resolution (analog)".
  - Rotary encoder: Number of division periods or cycles per encoder shaft revolution in DP/revolution
  - Linear encoder: Length of the division period in nm (nanometers/DP)
- Digital encoder
  The resolution of the digital encoder position is specified in "S-0-0602.x.22, Phys. encoder resolution (digital)":
  - Rotary encoder: Number of increments per encoder shaft revolution, specified in increments/encoder revolution
  - Linear encoder: Length of the shortest measurable distance in nm (nanometers/increment)
- Combined encoders
  Combined encoders consist of an analog and a digital encoder part.
  The physical encoder resolution is specified as follows:
  - For the analog encoder part in "S-0-0602.x.21, Phys. encoder resolution (analog)"
  - For the digital encoder part in "S-0-0602.x.22, Phys. encoder resolution (digital)"

Depending on the interface the encoder has been connected to, the structure instance "x" has a numerical value. See ↘ “ENCB - ENCE parameter structure”

The firmware-side interpretation of the values of S-0-0602.x.21 resp. S-0-0602.x.22 is defined by the configuration of the physical encoder properties in S-0-0602.x.2. If used as encoder 1/motor encoder, its type of motion has to comply with the one of the motor (rotary or linear).

.Resolution of original encoder position format (ENCB position format)

The Basic encoder evaluation generates the original encoder position (ENCB position) from the physical encoder position data. The original encoder position format (resolution) depends on the encoder type (rotary/linear) and, in the case of linear encoders, additionally on the encoder class (digital, analog or combined encoder). For the encoder type and the effective original position format, see parameter "S-0-0601.x.1, Encoder output data configuration".

- Digital encoders
  The resolution of the original encoder position corresponds to the physical resolution of the encoder.
  S-0-0601.x.21, position resolution = S-0-0602.x.22.
  - Rotary encoders: Resolution is specified in increments/encoder revolution.
  - Linear encoders: Resolution is specified in nm/increment.
- Analog encoders and combined encoders
  Via A/D converters, the analog sine/cosine signals are converted to digital position data with a resolution of 2^{18} increments/division period. The precision of this position depends on several factors (see chapter Precision/resolution). It is less than $1/2^{18}$ (indicated as incr./DP). The resolution of the original encoder position will then be as follows:
  - Rotary encoders:
    S-0-0601.x.21 = S-0-0602.x.21 * 2^{18} incr./DP
  - Linear encoders:
    S-0-0601.x.21 = 2^{18} incr./DP
    In order that the Extended encoder evaluation can convert the unscaled original encoder position to a scaled position in the Sercos position format, it needs to know the distance of a division period (DP). This is specified in parameter "S-0-0601.x.24, Extended position resolution (analog) ". "S-0-0601.x.24" corresponds to "S-0-0602.x.21, Phys. Encoder resolution (analog) ", indicated as nm/DP.

.Resolution of scaled Sercos III position format or incremental position format.

These two position scaling formats are described under .

.Encoder-related position range, (original encoder position range)

With ctrlX DRIVE, the position data of "Basic encoder evaluatio"n (ENCB) can be displayed up to a maximum of 48 bits. That is to say the position data have a value range of 0 to a maximum of (2^{48}-1) increments.

The position range of the ENCB position is specific to the type and kind of encoder. The definition of the ENCB position range is described in .

.Parameters involved

- S-0-0051, Actual position value, encoder 1
- S-0-0053, Actual position value, encoder 2
- S-0-0277, Encoder 1, type of position encoder
- S-0-0115, Encoder 2, type of position encoder
- S-0-0278, Maximum travel range
- S-0-0378, Absolute encoder range, encoder 1

- S-0-0379, Absolute encoder range, encoder 2

.Physical configuration of Basic encoder evaluation (ENCB)

IDN	Designation
S-0-0602.x.1	Phys. encoder type
S-0-0602.x.2	Phys. encoder properties
S-0-0602.x.21	Phys. encoder resolution (analog)
S-0-0602.x.22	Phys. encoder resolution (digital)
S-0-0602.x.136	Phys. encoder evaluation configuration

The placeholder "x" (structure instance) is the number of the device interface to which the encoder has been connected (see ↘ Encoder interfaces and related values of the ENCB parameter structure instance "x").

.Output data of Basic encoder evaluation (ENCB)

IDN	Designation
S-0-0600.x.1	Encoder status
S-0-0600.x.21	Position, 32 bits, fine
S-0-0600.x.22	Position, 32 bits, rough

The placeholder "x" (structure instance) is the number of the device interface to which the encoder has been connected (see ↘ Encoder interfaces and related values of the ENCB parameter structure instance "x").

.Configuration parameters of Basic encoder evaluation (ENCB)

IDN	Designation
S-0-0601.x.1	Encoder output data configuration

IDN	Designation
S-0-0601.x.12	Encoder output data refresh time
S-0-0601.x.21	Resolution of position
S-0-0601.x.22	Position overflow threshold
S-0-0601.x.23	Absolute position range
S-0-0601.x.24	Extended position resolution (analog)
S-0-0601.x.130	Basic encoder evaluation configuration, compact
S-0-0601.x.136	Serial number of encoder

The placeholder "x" (structure instance) is the number of the device interface to which the encoder has been connected (see ↘ Encoder interfaces and related values of the ENCB parameter structure instance "x").

.Extended input parameters (ENCE) for the Basic encoder output data

IDN	Designation
S-0-0610.x.1	Encoder status
S-0-0610.x.21	Position, 32 bits (input), fine
S-0-0610.x.22	Position, 32 bits (input), rough
S-0-0610.x.23	Marker position, 32 bits (input), fine
S-0-0610.x.24	Marker position, 32 bits (input), rough
S-0-0610.x.130	Extended encoder input data, compact

The number of the function is assigned to placeholder "x" (structure instance) (encoder 1/motor encoder: "1"; encoder 2: "2"

.Extended input parameters (ENCE) for the encoder data configuration

IDN	Designation
S-0-0611.x.1	Encoder output data configuration (input)
S-0-0611.x.11	Available encoder output data (input)
S-0-0611.x.21	Resolution of position, (input)
S-0-0611.x.22	Position overflow threshold, (input)
S-0-0611.x.23	Absolute position range, (input)
S-0-0611.x.12	Encoder output data cycle time (input)
S-0-0611.x.130	Sercos III encoder profile "extended", compact
S-0-0611.x.136	Serial number of encoder
The number of the function is assigned to placeholder "x" (structure instance) (encoder 1/motor encoder: "1"; encoder 2: "2"	