ENX 10 EASY / ENX 16 EASY

Encoders

Product Information

Document ID: 1 732 580-04

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ENX 10 EASY / ENX 16 EASY – Product Information

Figure 1 ENX 10 EASY (left) / ENX 16 EASY (right)

The ultra compact maxon EASY encoders use an interpolated Hall sensor angle measurement system to generate incremental quadrature output signals. They offer three channels (A, B, I) with differential electrical signals according to EIA-422 (20 mA maximum current) and feature a factory-programmable resolution in the range of 1 to 1024 impulses per turn.

The encoders are available in two form factors:

- Ø10 mm version for motors with outside diameter of Ø10 to Ø16 mm
- Ø16 mm version for motors with outside diameter of Ø16 mm and larger.

Both versions provide the same functionality, whereas the ENX 16 EASY is even more robust in terms of additional ESD protection circuitry and comprises a “standard pitch” 2.54 mm insulation displacement connector.

Pin-out for both versions is compatible to most maxon motor controllers with encoder interface.

The ENX EASY Absolute provides the same hardware while additionally offering a single-turn 12 bit absolute angle value with SSI or BiSS-C protocol.

Note
The listed data are for informational purposes only. None of the stated values or information may be used as an indicator of guaranteed performance.

1 Technical Data

1.1 Absolute Maximum Rating

Parameter	Conditions	Min	Max	Unit
Supply voltage (V_{cc})		–0.3	+6.0	V
Voltage at signal output (V_{signal})		–0.3	+6.0	V
Supply current (I_{dd})		–30	+220	mA
Signal output current (I_{signal})	A,B,I; no supply voltage	–100	+100	mA
	DATA; no supply voltage	–10	+10	mA
ESD voltage (V_{esd}), all pins	ENX 10 EASY (HBM 100 pF, 1.5 kΩ)		2	kV
	ENX 16 EASY (EN 61000-4-2)		>2	
Operating temperature (T_{amb})		–40	+100	°C
Storage temperature (T_{store})		–40	+105	°C
Humidity	Condensation not permitted	20	80	%rH

1.2 General Data

Parameter	Conditions	Min	Typ	Max	Unit
Supply voltage (V_{cc})		+4.5	5	+5.5	V
Supply current (I_{dd})	Output pulse frequency <100 kHz, load resistor ≥100 kΩ		17		mA

1.3 Incremental Interface

Parameter	Conditions	Min	Typ	Max	Unit
Number of channels	ChA, ChB, ChI		3		–
Resolution (N)	1…128, 256, 512, 1024 factory-configurable (recommended: 128)	1, 2, …	128	1024	cpt
Pulse frequency (f_{pulse})	Maximum output pulse frequency			500	kHz
Signal output current (I_{signal})	With Line Receiver EIA-422	–20		+20	mA
Signal voltage high (V_{high})	I_{signal} <20 mA, relative to V_{cc}	V_{cc}–0.5 V			V
Signal voltage low (V_{low})	I_{signal} <20 mA			0.5	V
Transition time (t_{trans})	Rise time/fall time ChA/B/I @ load resistor 100 Ω, C_{load} ≤200 pF		20	500	ns

1.4 Absolute Interface

Parameter	Conditions	Min	Typ	Max	Unit
Resolution (N)	SSI/BiSS mode 12 bit		4096		steps
Signal output current (I_{signal})	DATA output SSI/BiSS interface			20	mA
Signal voltage high (V_{high})	DATA output: I_{signal} <20 mA, relative to V_{cc}	V_{cc} –0.5 V			V
Signal voltage low (V_{low})	DATA output: I_{signal} <20 mA			0.5	V
Transition time (t_{trans})	DATA output: Rise time/fall time, C_{load} = 50 pF			60	ns
CLK Signal Frequency (f_{CLK})	SSI mode	0.04		4	MHz
	BiSS mode	0.6		10	MHz
Timeout (t_{out})	SSI mode	16			µs
	BiSS mode	2			µs
Minimum input level CLK HIGH (V_{high})	SSI/BiSS mode			3	V
Maximum input level CLK LOW (V_{low})	SSI/BiSS mode	0.8			V
Input resistance CLK (R_{input})			6.7		kΩ

1.5 Angle Measurement

All values at T = 25°C, n = 5000 rpm, V_{cc} = 5 V unless otherwise specified.
For definitions ➔page 9.

Parameter	Conditions	Min	Typ	Max	Unit
Counting direction of incremental signals (Dir)	Motor shaft movement for signal phase alignment “A leads B” as seen from the shaft end		CW		
Counting direction of absolute signals (Dir)	Motor shaft movement for increasing angle values as seen from the shaft end		CW		
State length (L_{state}), incremental	N≤128 cpt	45	90	135 *1	°el
	N=256 cpt	30	90	175	
	N=512, 1024 cpt		90		
Minimum state duration (t_{state}), incremental *2	n≤120‘000 rpm, T=-40…+105°C, N≤1024 cpt	500			ns
Index pulse width (L_{index}) (synchronized with ChA/B), incremental	N≤128 cpt	45	90	135	°el
	N=256 cpt	30	90	175	
	N=512, 1024 cpt		90		
Integral Nonlinearity (INL)	Maximum average angle error over one turn (all resolutions)		<1	2	°m
Differential Nonlinearity (DNL)	Maximum average state length error over one turn, n≤1024 cpt		<1	1	LSB
Repeatability (Jitter), resolution-dependent, incremental	N=256 cpt		<1		LSB
	N=512 cpt		<2 *3)		
	N=1024 cpt		<4 *3)		
Repeatability (Jitter), resolution-dependent	N=12 bit (EASY Absolute)		<4 *4)		
Repeatability (Jitter), all resolutions			<0.4		°m

Parameter	Conditions	Min	Typ	Max	Unit
Phase delay A to B (Phase θ), incremental	N≤256 cpt	45	90	135	°el
	N=512, 1024 cpt	15	90	165	
Angle hysteresis (Hyst) (➔Table 4)	N≤256 cpt			1	LSB
	N=512 cpt (configurable)	1 *3)	2		
	N=1024 cpt (configurable)	2 *3)	4		
Angle hysteresis EASY Absolute (Hyst)	N=12 bit (4096 steps)		2		LSB
Bandwidth of analog signal path	Typical equivalent bandwidth of single pole low-pass filter		16		kHz
Delay of digital signal path	Typical latency of digital signal processing		2		µs

Annotations: **1 Typical value for maximum state length*

**2 ➔Table 2*

**3) At resolutions 512 cpt and 1024 cpt and minimum hysteresis, occasional random state changes can occur at channel A or B – but never at both channels simultaneously (cf. minimum state duration t_{state} of 500 ns). These are caused by thermal noise and can be detected and correctly handled by a a quadrature decoder. maxon motor MAXPOS and EPOS Positioning Controllers as well as ESCON Servo Controllers are equipped with suitable quadrature decoders.*

**4) When reading the absolute angle at the same position, six standard deviations of the resulting sequence of values can approach 4 LSB.*

1.6 Mechanical Data

Parameter	Conditions	Value	Unit
Dimensions (D x L), without flange (➔Figure 8)	ENX 10 EASY	Ø10.0 x 8.5	mm
	ENX 16 EASY	Ø15.8 x 8.5	
Moment of inertia (Jt)	motor shaft Ø1…6 mm	0.01…0.09	g cm²
Standard cable length (Lc)	ENX 10 EASY	150	mm
	ENX 16 EASY	200	
	ENX 16 EASY Absolute	300	

Table 1 Technical Data

2 Absolute Encoder

The ENX16 EASY absolute encoder provides the joint functionality of a single-turn absolute encoder in parallel to the incremental output signals. Two interface protocol variants are factory-configurable: SSI and BiSS-C.

2.1 SSI Mode

- CLK input (5 V level, CMOS-compatible) at pin 4.
- DATA output (5 V level, driver strength 20 mA, CMOS and TTL-compatible) at pin 1.
- Maximum CLK frequency is 4 MHz.
- Minimum CLK frequency is 40 kHz.
- Timeout is 16 µs; wait time after reading of last bit must be larger than t_{out}.
- Protocol: 13 bit data, MSB first, last bit always zero, gray coded
- A complete reading cycle at maximum clock takes at least $13 \cdot \frac{1}{4MHz} + 16\mu s = 19.25\mu s$.

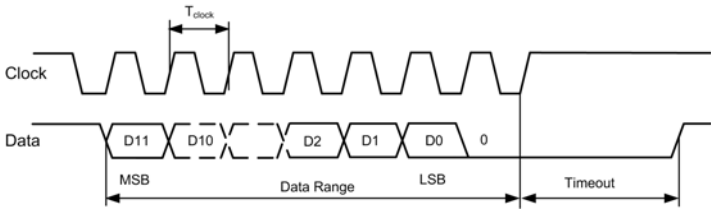


Figure 2 Timing of EASY Absolute in SSI Mode

2.2 BiSS-C Mode

- CLK input (5 V level, CMOS-compatible) at pin 4.
- DATA output (5 V level, driver strength 20 mA, CMOS and TTL-compatible) at pin 1.
- Maximum CLK frequency is 10 MHz.
- Minimum CLK frequency is 600 kHz.
- Timeout is 2 µs; wait time after reading of last bit must be larger than t_{out}.
- Protocol: 3 bit start sequence {Ack, Start, CDS} fixed values, 12 bit data (MSB first), 2 bits Error/ Warning, 6 bit CRC (polynomial: 0b1000011, inverted mode).
- A complete reading cycle at maximum clock takes at least $23 \cdot \frac{1}{10MHz} + 2\mu s = 4.3\mu s$.
- The interface is BiSS-C-compatible. For more information to the BiSS-C interface specification ➔http://biss-interface.com/ (section “Downloads”).
  In the simplest configuration, the controller is the master and ENX EASY Absolute the only slave.

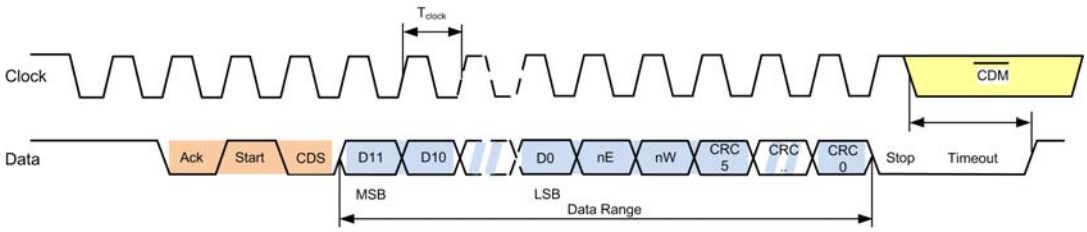


Figure 3 Timing of EASY Absolute in BiSS-C Mode

2.3 Angle Alignment

The encoder's angle value “zero” is factory-programmed to the commutation angle “zero” (➔Figure 4).

- When assembled onto a motor with several pole pairs (n), the **ENX 16 EASY Absolute** (part numbers 488783 and 488782) will show this angle value zero **once per mechanical turn**.
- Due to its multiple sets of pole pairs, the **motor** will show this commutation angle **n times per mechanical turn**.

The angle Zero is identical to the index pulse position.

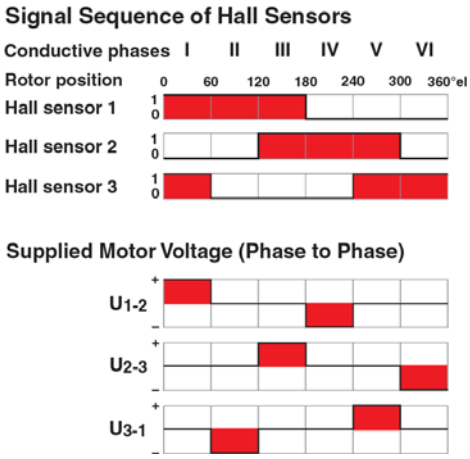
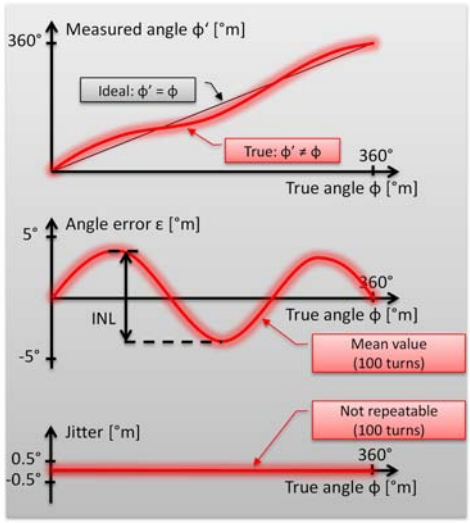
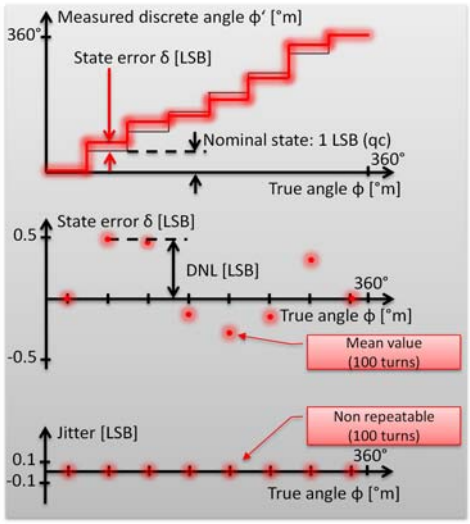
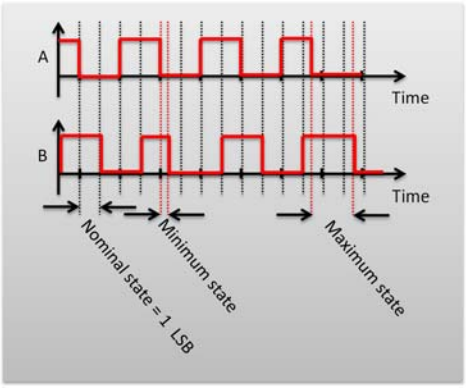


Figure 4 Block Commutation of EC (BLDC) Motors – Definition of Phases

3 Definitions

Metric	Definition	Illustration
Angle Error [°m]	Difference of measured and true angular shaft position at each position.	
Average Angle Error [°m]	Average of Angle Error over a number of turns.	
Integral Nonlinearity (INL) [°m]	Peak-to-peak value of Average Angle Error.	
Jitter (Repeatability) [°m] or [LSB]	Six standard deviations of Angle Error per turn (over one turn, at a given number of turns). **Jitter [°m]** is typically independent of resolution and defines the maximum useful positioning repeatability. **Jitter [LSB]** is resolution-dependent. At given Jitter [°m], the value is roughly proportional to resolution.	
Least Significant Bit (LSB)	Minimum measurable difference between two angle values at given resolution (= quadcount, = State).	
State Error [LSB]	Difference between actual state length and average state length.	
Average State Error [LSB]	Average of State Error over a number of turns for each state of a turn.	
Differential Nonlinearity [DNL]	Maximum positive or negative Average State Error.	
Minimum State Length [°el]	Minimum measured state length within a number of turns relative to pulse length.	
Maximum State Length [°el]	Maximum measured state length within a number of turns relative to pulse length.	
Minimum State Duration [ns]	By chip limited minimum time separation between two A/B transitions.	

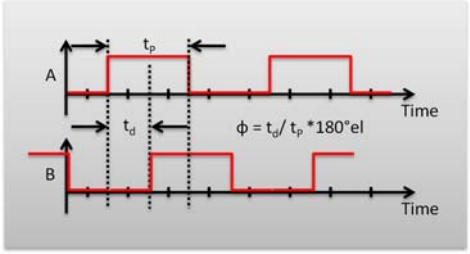
Metric	Definition	Illustration
Phase delay θ [°el]	Time difference of rising edge A to B relative to duration of positive level of A.	

Table 2 Definitions

4 Typical Measurement Results

4.1 Angle Error per Turn, calibrated

The average angle error [°m] and the repeatability (Jitter) [°m] are independent of the chosen resolution. The metrics given in LSB are resolution-dependent.

Below graphs show angle error measurements of one same EASY encoder at different resolutions under following conditions: Measurement of 25 turns at V_{cc}=5 V, n=5000 rpm, 1 kΩ load, T=25°C.

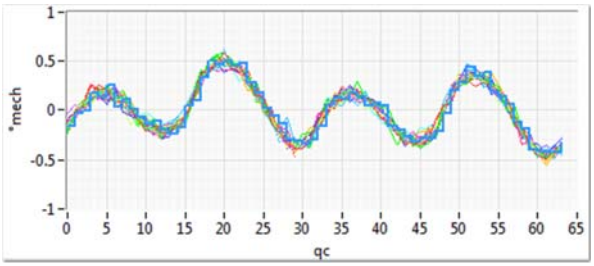
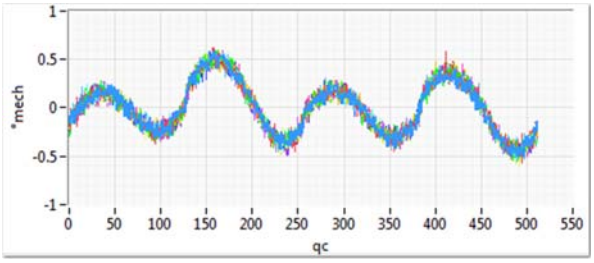
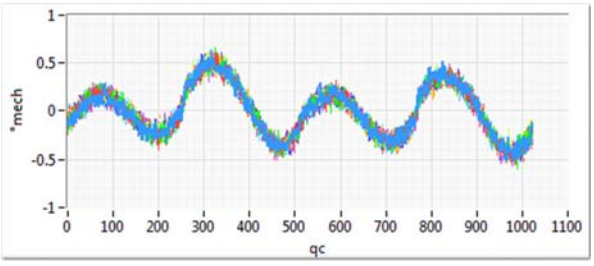
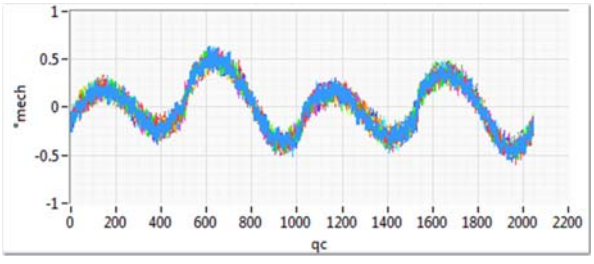
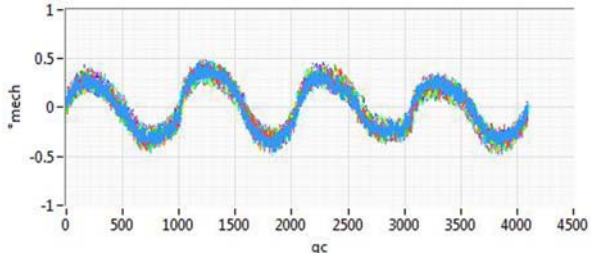
Resolution	Graph	Analysis	
16 cpt		INL Jitter DNL Min State Max State	1°m 0.3°m = 0.04 LSB 0.07 LSB 0.95 LSB = 85°el 1.06 LSB = 96°el
128 cpt		INL Jitter DNL Min State Max State	1°m 0.3°m = 0.4 LSB 0.2 LSB 0.7 LSB = 60°el 1.4 LSB = 124°el
256 cpt		INL Jitter DNL Min State Max State	1°m 0.3°m = 0.8 LSB 0.3 LSB 0.55 LSB = 50°el 1.7 LSB = 156°el
512 cpt		INL Jitter DNL Min State Max State	1°m 0.3°m = 1.6 LSB 0.44 LSB 0.49 LSB = 43°el 2.3 LSB = 205°el
1024 cpt		**Note:** The measurements were taken from a different unit than the others. INL Jitter DNL Min State Max State	 0.75°m 0.23°m = 2.5 LSB 0.5 LSB 0.37 LSB = 33°el 2.8 LSB = 250°el

Table 3 Typical Measurement Results

4.2 Temperature Dependence

INL, DNL and Min State are basically temperature-independent. Max State and, in particular, Jitter increases with temperature (due to thermal noise). The increasing Max State is the consequence of the increasing Jitter.

Figure 5 shows the temperature dependence of seven samples of EASY encoders under following conditions: V_{cc}=5 V, 10‘000 rpm, 1 kΩ load, 256 cpt.

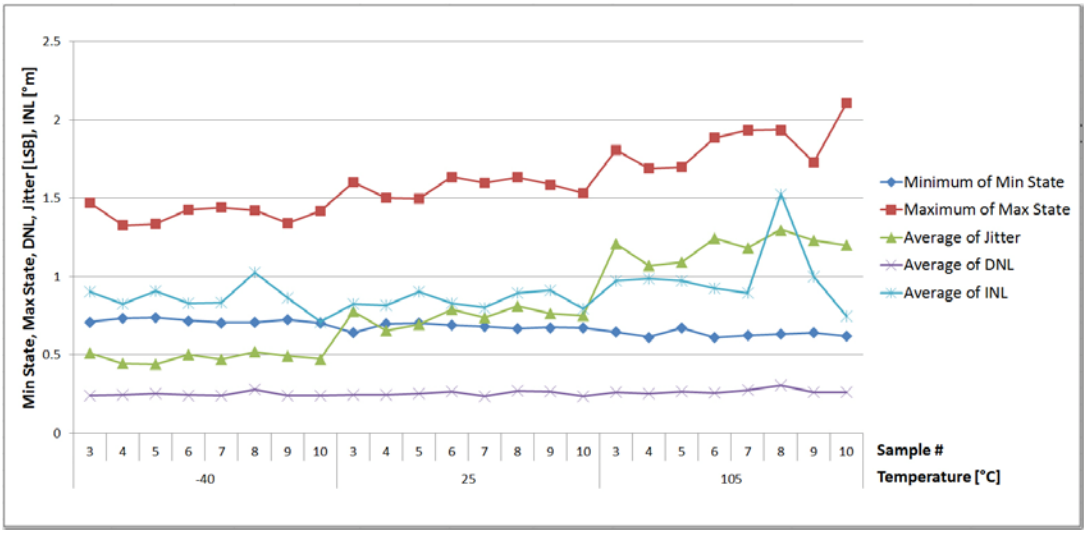


Figure 5 Temperature Dependence

4.3 Resolution Dependence

INL and Jitter [°m] are independent of resolution (➔Table 3), the resolution-dependent metrics deteriorate with increased resolution. The maximum useful resolution for positioning applications is 256 cpt with Jitter <1 LSB at room temperature.

Figure 6 shows the resolution dependence of nine samples of EASY encoders under following conditions: V_{cc}=5 V, 10‘000 rpm, 1 kΩ load, 25°C.

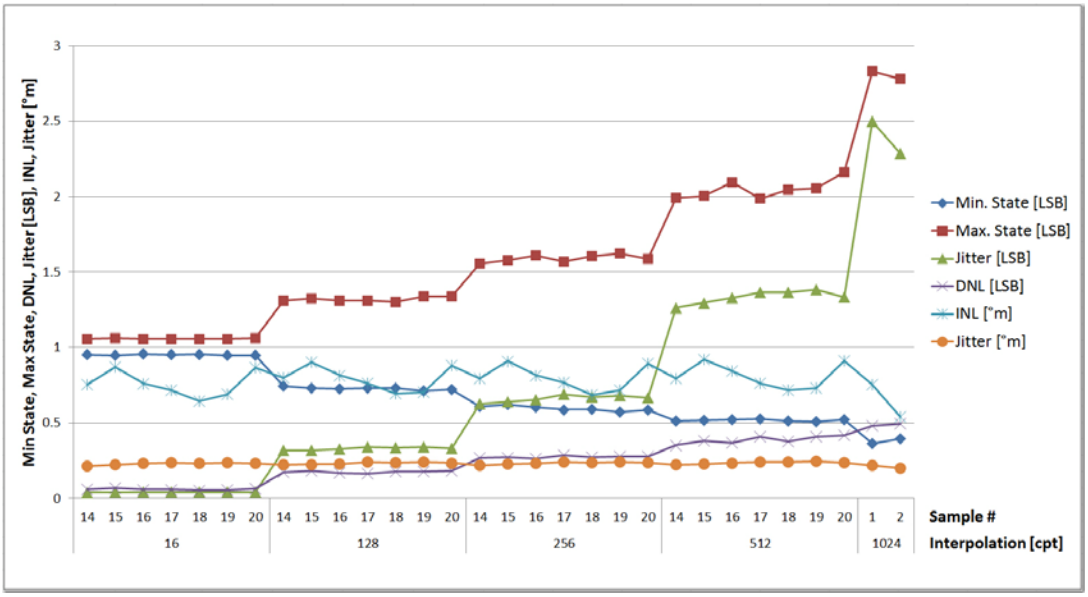


Figure 6 Resolution Dependence

4.4 Hysteresis

When turning the direction of movement, digital hysteresis suppresses multiple switching at the turning position. Hysteresis has the same effect as a mechanical slip at the turning position. When approaching the switching position from the same direction, the location of the transition (A or B) will always be created at the same position. Figure 7 shows the generated quadrature signals as a function of angular position at a direction change in view of digital hysteresis.

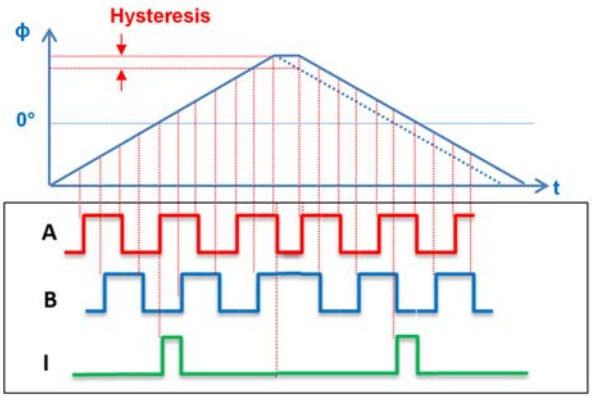


Figure 7 Effect of Hysteresis on Pulse Sequence at Rotation Direction Change (CW/CCW)

For resolutions ≤256 cpt, ENX EASY encoders are programmed to a digital hysteresis of 1 LSB (1 quad-count). For higher resolutions of 512 cpt and 1024 cpt, the standard hysteresis is 0.35°m (2 LSB at 512 cpt, 4 LSB at 1024 cpt). At room temperature (for jitter <1LSB), no spontaneous signal changes occur in this mode. A reduced hysteresis of 0.17°m (1 LSB at 512 cpt, 2 LSB at 1024 cpt) can be chosen during configuration. In this mode, spontaneous changes of the A or B signal can occur at low speed due to thermal noise causing jitter >1LSB.

Resolution	Standard Hysteresis	Reduced Hysteresis
1…64 cpt	1.4°m / ≤1 LSB	not applicable
65…128 cpt	0.7°m / ≤1 LSB	not applicable
256 cpt	0.35°m / 1 LSB	not applicable
512 cpt	0.35°m / 2 LSB	0.17°m / 1 LSB
1024 cpt	0.35°m / 4 LSB	0.17°m / 2 LSB
12 bit	0.17°m / 2 LSB	not applicable

Table 4 Default/programmable Hysteresis for different Resolutions

5 Dimensional Drawings

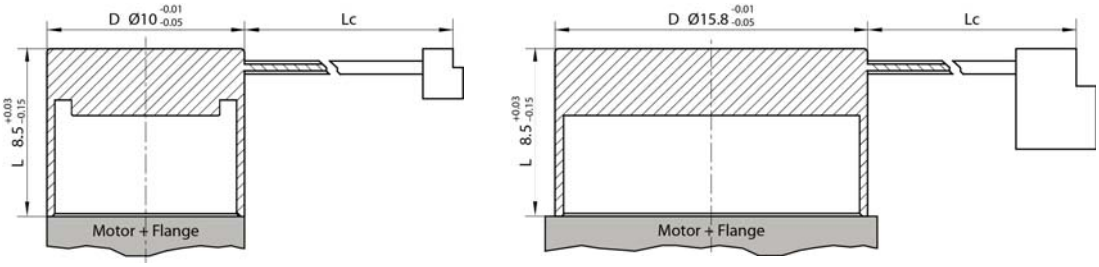


Figure 8 Dimensional Drawing [mm] – ENX 10 EASY (left) / ENX 16 EASY (right)

6 Pin Assignment

Maximum permitted Supply Voltage
- *Make sure that supply power is within stated range.*
- *Supply voltages exceeding the stated range, or wrong polarity will destroy the unit.*
- *Connect the unit only when supply voltage is switched off (V_{cc}=0).*

Figure 9 Cable Plug – ENX 10 EASY (left) / ENX 16 EASY / Absolute (right)

Pin	Signal	Description
1	SSI/BiSS DATA	Absolute encoder Data
2	V_{cc}	Power supply voltage
3	GND	Ground
4	SSI/BiSS CLK	Absolute encoder Clock
5	ChA/	Channel A complement
6	ChA	Channel A
7	ChB/	Channel B complement
8	ChB	Channel B
9	ChI/	Channel I (index) complement
10	ChI	Channel I (index)

Table 5 Cable Plug – Pin Assignment

Assignment Pin 1 and Pin 4
Externally applied voltages at these pins can destroy the device.

Specifications		
ENX 10 EASY	Connector	IDC socket, pitch 1.27 mm, 5 x 2 poles
	Mating plug	Pin header, pitch 1.27 mm, 5 x 2 poles (e.g. Samtec FTSH series)
ENX 16 EASY / Absolute	Connector	IDC socket, pitch 2.54 mm, 5 x 2 poles
	Mating plug	Pin header, pitch 2.54 mm, 5 x 2 poles (EN 60603-13/DIN 41651)

Table 6 Cable Plug – Specifications

7 Output Circuitry

Conceptual schematics of outputs ENX 10 EASY (➔Figure 10) and ENX 16 EASY (➔Figure 11) including ESD protection circuitry.

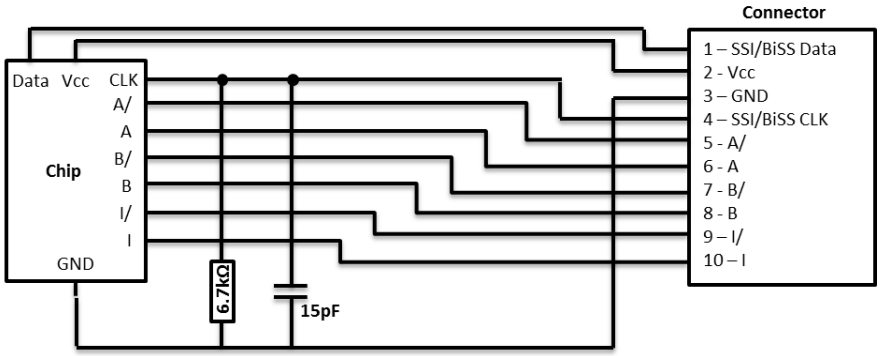


Figure 10 Output Circuitry – ENX 10 EASY

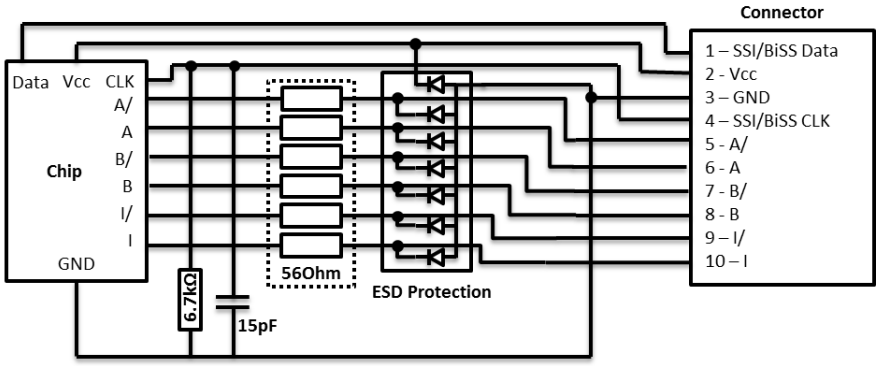


Figure 11 Output Circuitry – ENX 16 EASY / Absolute

8 Accessories

Order number	Description	
405120	Plug-in adapter	To connect the ENX 10 EASY to… • EPOS2 Positioning Controllers, • ESCON Servo Controllers and • other controllers.
488167	Adapter EASY Absolute	To connect the ENX10 EASY or ENX16 EASY to a maxon controller with absolute encoder interface: • EPOS2 50/5 (SSI only) • EPOS3 70/10 EtherCat (SSI only) • EPOS2 70/10 (SSI only) • MAXPOS 50/5 (SSI or BiSS-C) Suitable signal cables sold separately.
300586	Signal cable	To connect the adapter 488167 to an EPOS2 50/5 or EPOS3 EtherCAT controller
378173		To connect the adapter 488167 to an EPOS2 70/10 controller
451290		To connect the adapter 488167 to a MAXPOS controller
For further details ➔maxon catalog		

Table 7 Suitable Accessories

Adapter EASY Absolute (488167)

The adapter converts the single-ended clock and data signals of an ENX EASY Absolute into TIA/EIA RS-422-compliant differential clock and data lines suitable to most absolute encoder controller inputs.

Driver/receiver component used: SN75179BD or compatible.

Parameter	Conditions	Min	Typ	Max	Unit
Operating temperature (T_{amb})		0		70	°C
Supply voltage (V_{cc})		4.75	5	5.25	V
Supply current (I_{cc})	Without encoder, no load		57	70	mA
Maximum Clock frequency (f_{CLK})				10	MHz

Note

The operating voltage range of the adapter is narrower than that of the ENX EASY Absolute. The controller's voltage supply at the absolute encoder interface must provide the current of both adapter and encoder (typically a total of 74 mA).

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