maxon

ENX EASY INT

Product Information

ENX EASY INT Encoders
Product Information
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BiSS	© iC-Haus GmbH, DE-Bodenheim
CLIK-Mate™ Micro-Fit™ Mega-Fit®	© Molex, USA-Lisle, IL

ENX EASY INT Encoders – Product Information



ENX 13 EASY INT



ENX 16 EASY INT

Figure 1 Overview (excerpt)

The ultra compact maxon EASY encoders use an interpolated Hall sensor angle measurement system to generate angle information of up to 4096 steps per turn. Electively or in combination available are incremental square wave signals, absolute angular values (SSI or BiSS-C), and/or commutation signals.

The encoders are available for diameter-compliant mounting on motors of the ECX series with outside diameters of 13, 16, 19, and 22 mm:

- ENX EASY INT – incremental encoder with differential output signals
- ENX EASY INT COMM – incremental encoder with commutation signals
- ENX EASY INT Absolute – absolute encoder
- ENX EASY INT Absolute COMM – absolute encoder with commutation signals
- ENX COMM – commutation signals, only

The encoders are available in versions with individual wires, connectors, or connection pins. All versions have reverse polarity protection.

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

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.

The following absolute encoders in the version with BiSS-C-interface have the BiSS certification:

- ENX 13 EASY INT Absolute
- ENX 16 EASY INT Absolute
- ENX 19 EASY INT Absolute
- ENX 22 EASY INT Absolute

The corresponding certificate is available for download in the maxon web shop. Further information on the BiSS-C mode can be found in ➔ chapter “2.2 BiSS-C Mode” on page 10.

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	
ESD voltage (V_{esd}), all pins	EN 61000-4-2		>2	kV
Operating temperature (T_{amb}) *1		–40	+125	°C
Storage temperature (T_{store}) *1		–40	+125	°C
Humidity (condensation not permitted)	*1	20	100	%rH

*Annotation *1* *The included connectors are designed for a temperature range of –40…+105 °C and a humidity of 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		16 / 22 *2		mA

*Annotation *2* *The typical supply current is 16 mA for encoders with the optimized chip revision. The typical supply current is 22 mA for encoders with the previous chip revision. Production of encoders with the optimized chip revision will start in 2027.*

1.3 Incremental Interface

Parameter	Conditions	Min	Typ	Max	Unit
Number of channels	ChA, ChB, ChI		3		–
Counts per turn (N) (factory-configurable)	1…1024	1	256	1024	cpt
Pulse frequency (f_{pulse})			4		MHz
Signal output current (I_{signal})	With Line Receiver EIA-422	–60	±20	+60	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		10	25	ns

1.4 Absolute Interface

Parameter	Conditions	Min	Typ	Max	Unit
Steps per turn (N)	SSI/BiSS-C mode 12 bit		4096		steps
Signal output current (I_{signal})	DATA output SSI/BiSS interface	–60	±20	+60	mA
Signal voltage high (V_{high})	DATA output: I_{signal} <20 mA, relative to V_{cc}	V_{cc} –1 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
System Clock (f_{sys})		0.8	1.0	1.2	MHz
CLK Signal Frequency (f_{clk})	SSI mode	0.04		4	MHz
	BiSS-C mode	0.05		10 *3	
Timeout (t_{out})	SSI mode	20			µs
	BiSS-C mode	1.5* ($1/f_{clk}$)+ 3.75 µs			
Minimum input level CLK HIGH (V_{high})	SSI/BiSS-C mode	2			V
Maximum input level CLK LOW (V_{low})	SSI/BiSS-C mode			0.8	V
Input resistance CLK (R_{input})			12		kΩ

*Annotation *3* *A maximum CLK signal frequency of 5 MHz applies to the certified BiSS-C mode.*

1.5 Commutation Interface

Parameter	Conditions	Min	Typ	Max	Unit
Number of channels	H1, H2, H3		3		–
Pulse frequency (f_{pulse})	Maximum output pulse frequency		53		kHz
Signal output current (I_{signal})		–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 H1/H2/H3 without load		10	25	ns

1.6 Angle Measurement

Conditions *All values at T = 25°C, n = 10000 rpm, V_{cc} = 5 V unless otherwise specified.*

Definitions *See ➔page 11.*

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}) and index pulse width (L_{index} synchronized with ChA/B), incremental	N=1…128, 256, 512 cpt	45	90	135	°e
	N=1024 cpt	30	90	160	
	N=500, 1000 cpt and other non-binary number of impulses *4	30	90	250	
Minimum state duration (t_{state}), incremental	f_{pulse}≤2.0 MHz		125		ns
	f_{pulse}>2.0 MHz		62.5		
Integral Nonlinearity (INL)	All number of impulses		<1	2	°m
Differential Nonlinearity (DNL)	N=1…128, 256, 512 cpt		0.3	0.5	LSB
	N=1024 cpt		0.6	0.9	
	N=500, 1000 cpt and other non-binary number of impulses *4			2	
Repeatability (Jitter), incremental	N=512 cpt		0.5		LSB
	N=1024 cpt		1		
Repeatability (Jitter)	All number of impulses		0.1		°m
Repeatability (Jitter), absolute	SSI/BiSS-C mode 12 bit		1 *5		LSB
Phase delay A to B (Phase θ), incremental	N=1…512 cpt	45	90	135	°e
	N=513…1024 cpt	15	90	165	
Angle hysteresis (Hyst)	N=1…1024 cpt		0.17		°m
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
Maximum commutation angle error (maxCAE)	Variants with commutation signals (COMM)		2		°e

Annotations

**4 For non-binary pulse counts, the encoder systematically omits individual states from the maximum possible sequence of states per revolution. This increases the length of the related output pulses. This has a negative effect on the performance values that depend on resolution.*

**5 For repeated readings of the absolute angle at a constant angular position, six times the standard deviation of the measured values can reach 1 LSB.*

1.7 Angle Alignment

The angle value “zero” of the absolute encoder, the index of the incremental encoder, as well as the rising edge of the commutation signal H1 are factory-programmed to the commutation angle “zero” of the used EC (BLDC) motor. The "zero" commutation angle is 30°e after the zero crossing of the back EMF (➔Figure 2).

- When assembled onto a motor with several pole pairs (n), the absolute encoders will show the angle value “zero” and the incremental encoders the index **once per mechanical turn**.
- Due to its multiple sets of pole pairs, the **motor** will show this commutation angle **n times per mechanical turn**.

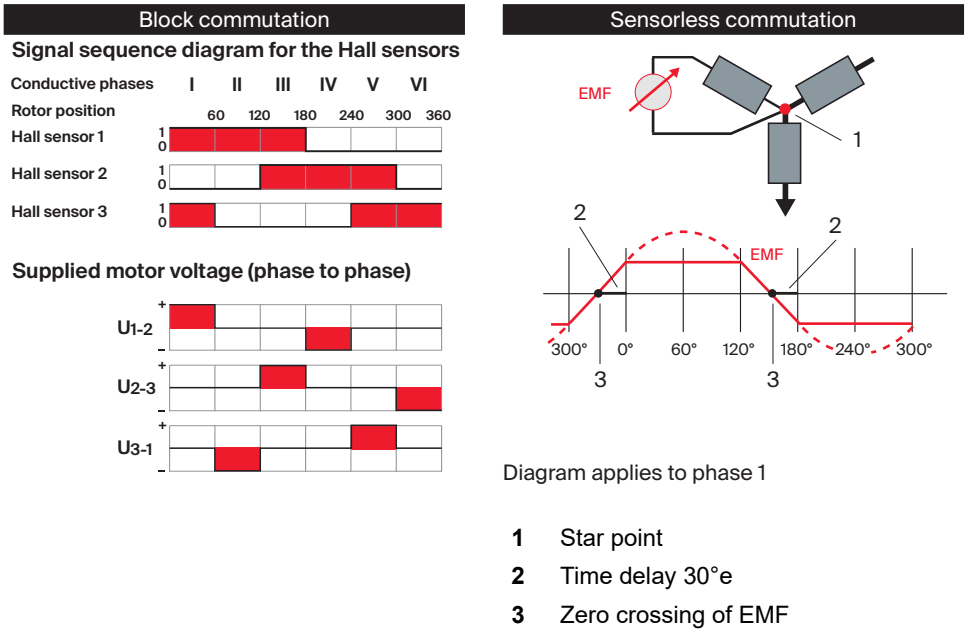


Diagram applies to phase 1

1 Star point
2 Time delay 30°e
3 Zero crossing of EMF

Figure 2 Block Commutation of EC (BLDC) Motors – Definition of Phases

1.8 Sterilizability

You can sterilize ENX EASY INT encoders with steam in an autoclave when they are installed on a suitable, sterilizable motor. Suitable motors include ECX SPEED motor versions identified as sterilizable.

Parameter	Conditions
Sterilization method	Steam sterilization in an autoclave
Temperature	+134 ±4 °C
Pressure resistance	Up to 2.3 bar
Relative humidity	100 %
Cycle duration	18 min
Number of sterilization cycles	Typically 1000

Connector

The connector is not suitable for sterilization. Remove the connector before sterilization.

1.9 Mechanical Data

Parameter	Conditions	Value	Unit
Dimensions	ENX 13 EASY INT ENX 13 COMM	Ø13	mm
	ENX 16 EASY INT ENX 16 COMM	Ø16	
	ENX 19 EASY INT ENX 19 COMM	Ø19	
	ENX 22 EASY INT ENX 22 COMM	Ø22	
Moment of inertia (Jt)	motor shaft Ø1…8 mm	0.01…0.7	g cm²
Standard cable length (Lc)	ENX 13 EASY INT ENX 13 COMM ENX 16 EASY INT ENX 16 COMM ENX 19 EASY INT ENX 19 COMM ENX 22 EASY INT ENX 22 COMM	200	mm

ENX 13 | 16 | 19 | 22 EASY INT COMM

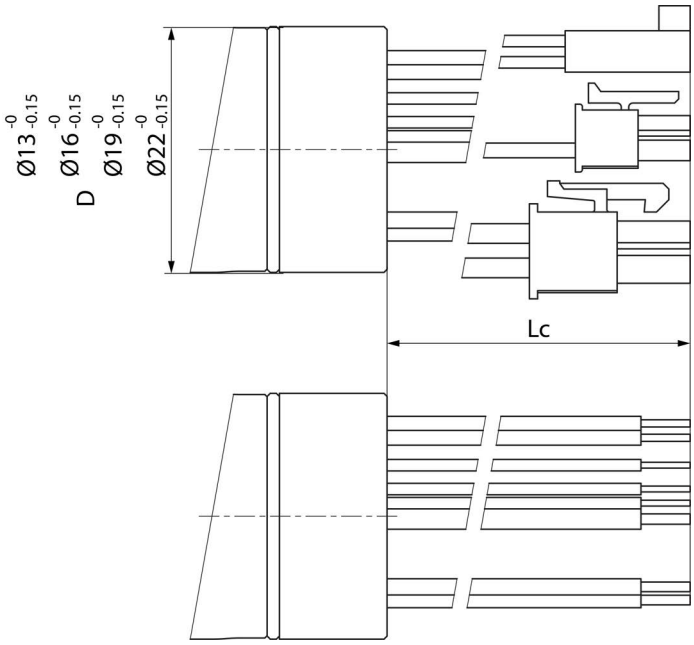


Figure 3 ENX 13 | 16 | 19 | 22 EASY INT COMM – Dimensional Drawing [mm]

Continued on next page.

ENX 13 | 16 | 19 | 22 EASY INT ABSOLUTE

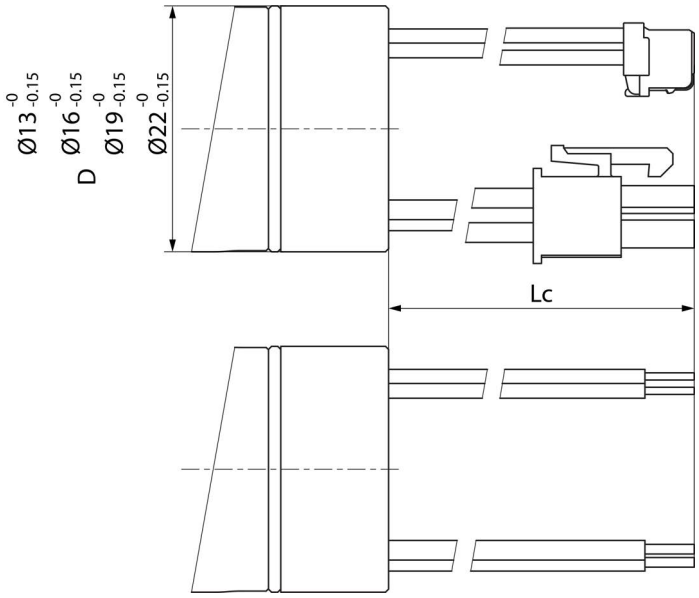


Figure 4 ENX 13 | 16 | 19 | 22 EASY INT Absolute – Dimensional Drawing [mm]

ENX 13 | 16 | 22 COMM

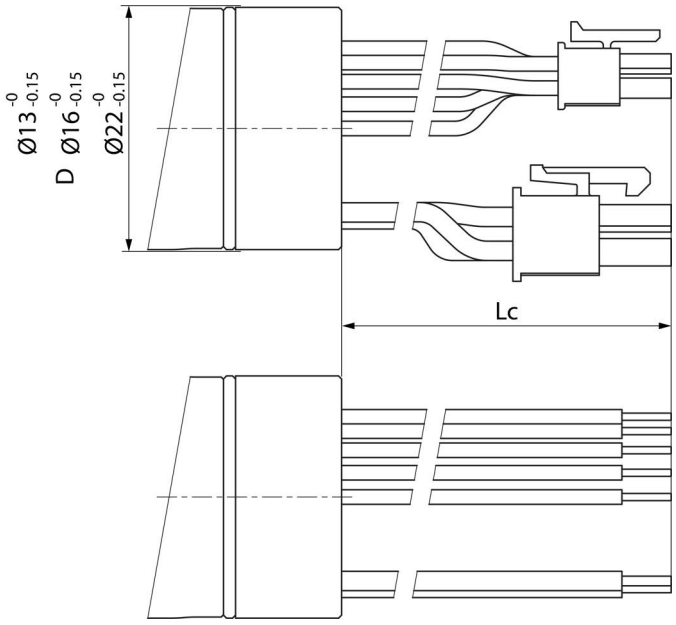


Figure 5 ENX 13 | 16 | 22 COMM – Dimensional Drawing [mm]

2 ABSOLUTE ENCODER

The «ENX EASY INT» absolute encoders provide the functionality of a single-turn absolute encoder. Two interface protocol variants are factory-configurable; SSI and BiSS-C.

2.1 SSI Mode

- The wait time after reading of last bit must be larger than Timeout (t_{out}).
- Protocol: 13 bit data, MSB first, last bit always zero, gray coded
- A complete reading cycle at maximum clock rate can be calculated using the following formula:

$$13 \cdot \frac{1}{4MHz} + t_{out} .$$

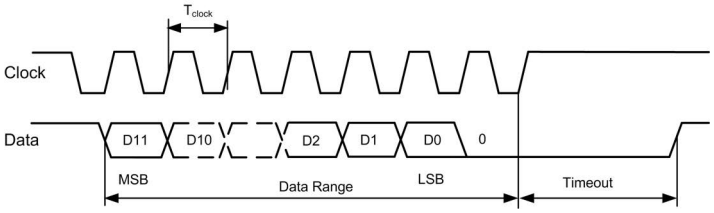


Figure 6 Timing of EASY INT Absolute in SSI Mode

2.2 BiSS-C Mode

- The wait time after reading of last bit must be larger than Timeout (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, binary coded).
- A complete reading cycle at maximum clock rate takes at least as follows:

ENX 13…22 EASY INT

$$23 \cdot \frac{1}{10MHz} + \left(1.5 \cdot \frac{1}{10MHz} + t_{out}\right) .$$

- The absolute encoders listed on ➔page 3 have a certified BiSS-C interface. A BiSS master (e.g. motion controller) can automatically configure its interface to the sensor by using the "Auto Profile Detection Concept" (number of bits ST, CRC, nE, nW). Encoder is pre-configured in this respect according to the BiSS Profile 1 (BP1) specification. For more details on the specification of the BiSS-C interface and BiSS Profile 1: ➔http://biss-interface.com/ (section “Downloads” ➔ "EDS and Profile Definitions").
- In the simplest configuration, the controller is the master. The ENX EASY INT Absolute encoder is the only slave.

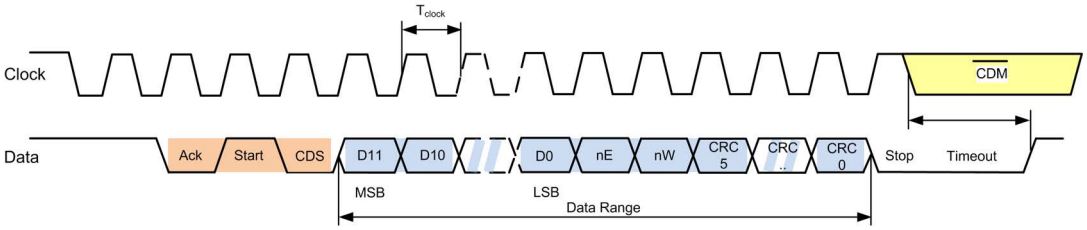
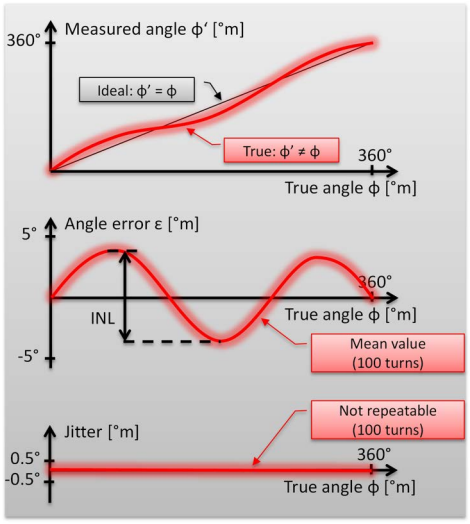
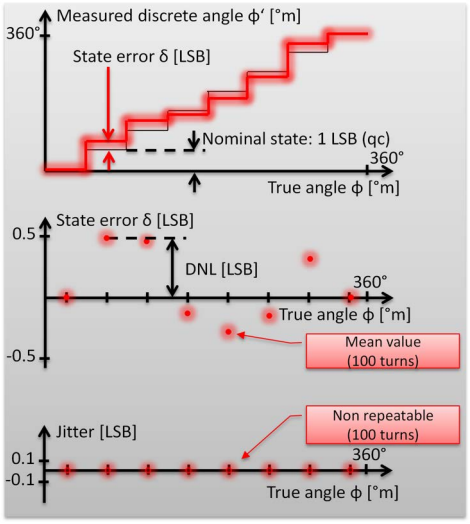
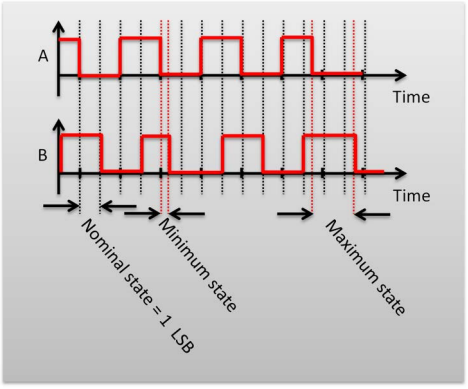


Figure 7 Timing of EASY INT Absolute in BiSS-C Mode

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 at each position, over a given 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 (at each position, over a given number of turns). **Jitter [°m]** is typically independent of the 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 [°e]	Minimum measured state length within a number of turns relative to pulse length.	
Maximum State Length [°e]	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.	

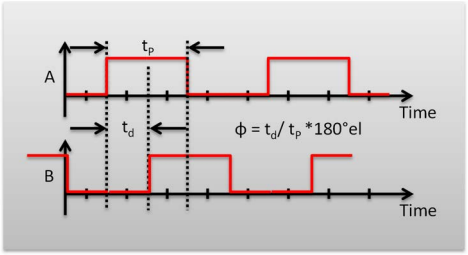
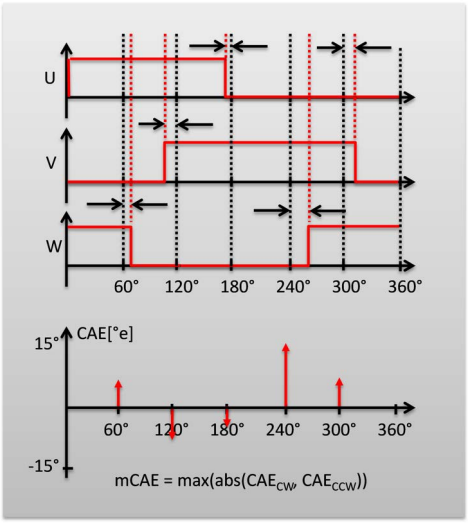
Metric	Definition	Illustration
Phase delay θ [°e]	Time difference of rising edge A to B relative to duration of positive level of A.	
Maximum commutation angle error (maxCAE) [°e]	Maximum positive or negative deviation of the individual switching points of the commutation signals (reference signals), determined over a certain number of turns.	

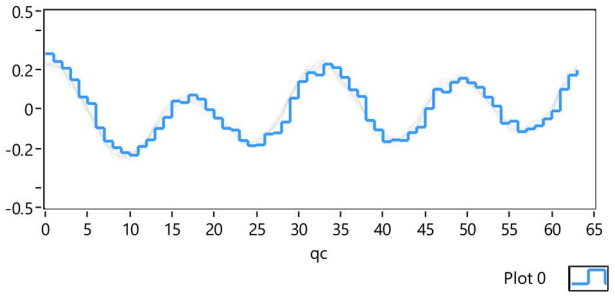
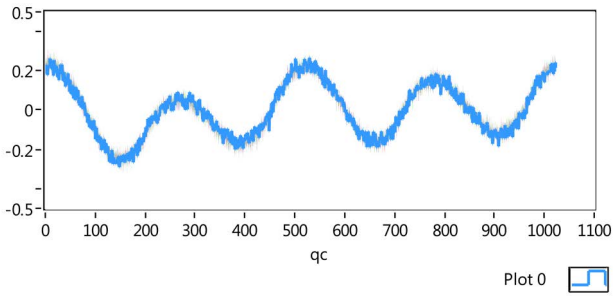
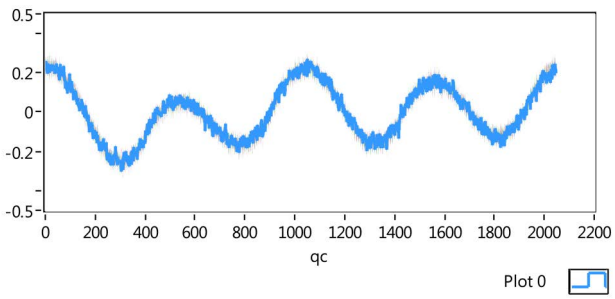
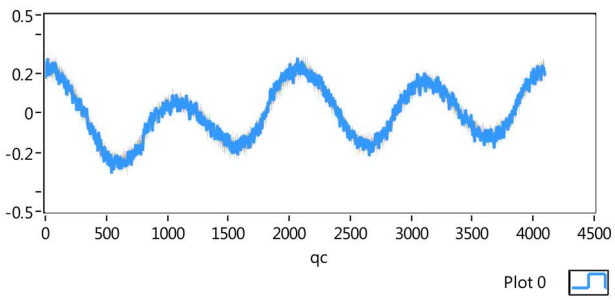
Table 1 Definitions

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 an ENX 13 EASY INT, configured as incremental encoder in various resolutions and as absolute encoder with maximum resolution under following conditions: Measurement of 25 turns at V_{cc}=5 V, n=10000 rpm, T=25°C.

Resolution	Graph	Analysis	
16 cpt		INL Jitter DNL Min State Max State	0.5°m 0.1°m = 0.02 LSB 0.03 LSB 0.97 LSB = 87°e 1.02 LSB = 92°e
256 cpt		INL Jitter DNL Min State Max State	0.5°m 0.1°m = 0.25 LSB 0.12 LSB 0.9 LSB = 81°e 1.1 LSB = 99°e
512 cpt		INL Jitter DNL Min State Max State	0.5°m 0.1°m = 0.5 LSB 0.3 LSB 0.85 LSB = 76°e 1.3 LSB = 117°e
1024 cpt		INL Jitter DNL Min State Max State	0.5°m 0.1°m = 1 LSB 0.5 LSB 0.8 LSB = 72°e 1.5 LSB = 135°e

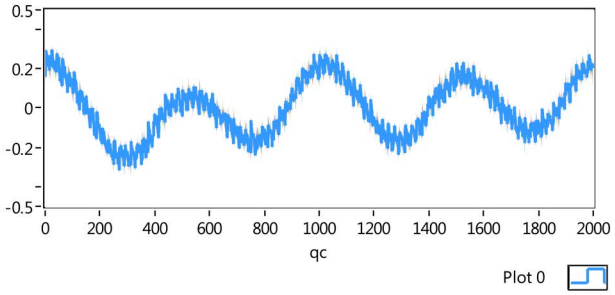
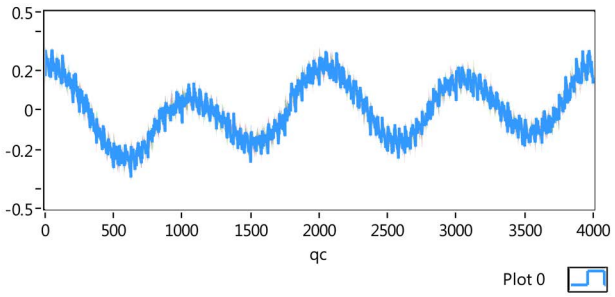
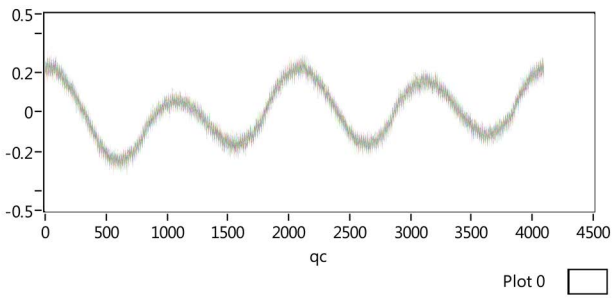
Resolution	Graph	Analysis	
500 cpt (non-binary)		INL Jitter DNL Min State Max State	0.5°m 0.1°m = 0.5 LSB 0.75 LSB 0.85 LSB = 76°e 1.75 LSB = 158°e
1000 cpt (non-binary)		INL Jitter DNL Min State Max State	0.5°m 0.1°m = 1 LSB 1.5 LSB 0.75 LSB = 67°e 2.5 LSB = 225°e
12 bit (Absolute)		INL Jitter	0.5°m 0.1°m = 1 LSB

Table 2 Typical Measurement Results

4.2 Temperature Dependence

Basically, INL, DNL, and State are temperature-independent. Due to thermal noise, Jitter increases, respectively repeatability decreases with rising temperature.

Figure 8 shows the temperature dependence of eight different ENX 13 EASY INT samples under the following conditions: V_{cc}=5 V, 10‘000 rpm, 1 kΩ load, 1024 cpt.

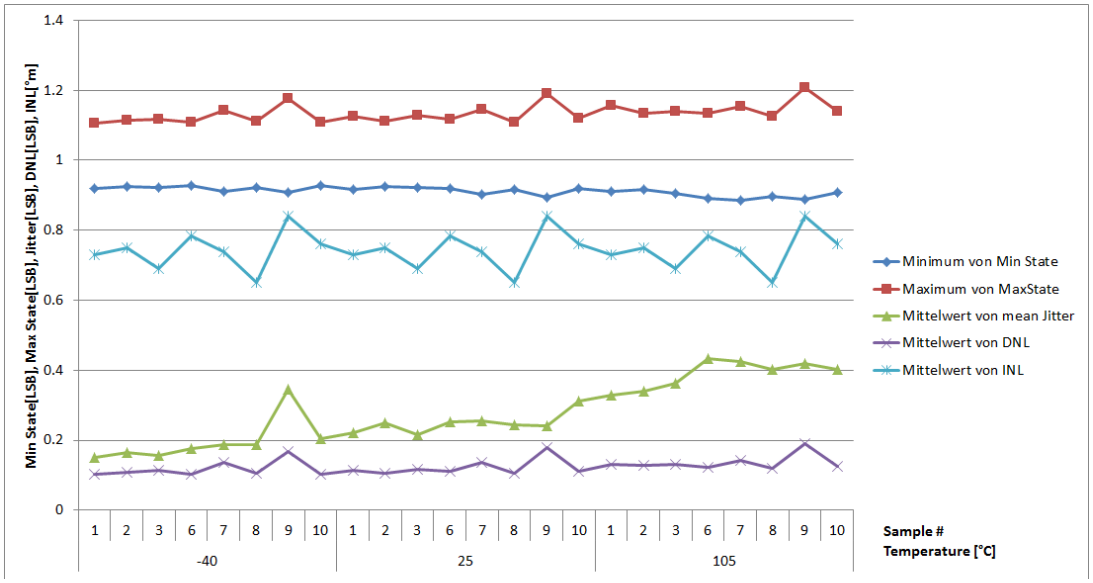


Figure 8 Temperature Dependence

4.3 Resolution Dependence

INL and Jitter [°m] are independent of resolution (➔Table 2). Resolution-dependent metrics deteriorate with increased resolution, particularly with non-binary resolutions (➔Figure 10)

Figure 9 shows the resolution dependence of eight different ENX 13 EASY INT samples under following conditions: V_{cc}=5 V, 10‘000 rpm, 1 kΩ load, 25°C, binary resolution

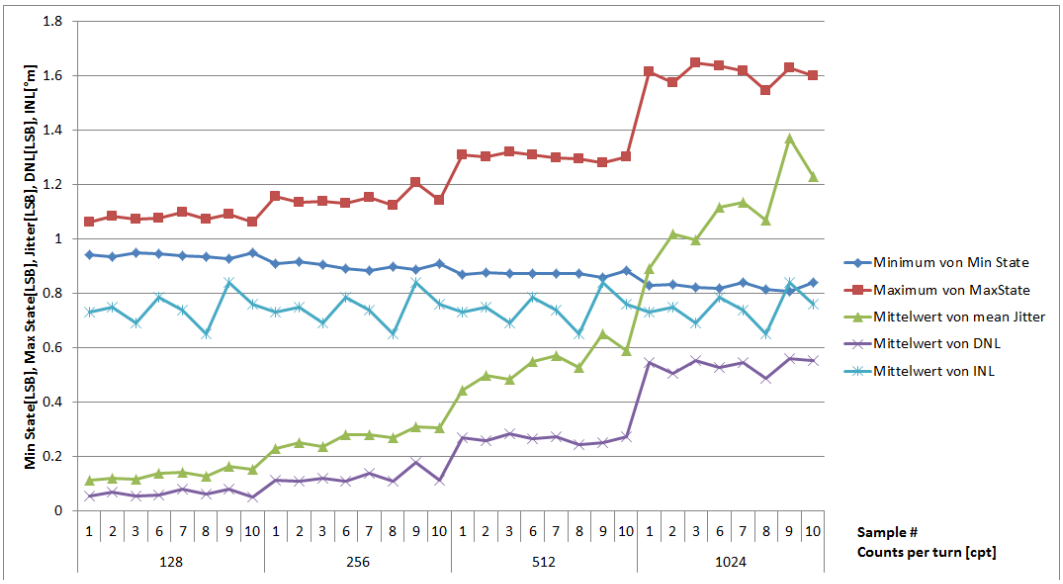


Figure 9 Resolution Dependence (binary Resolutions)

Figure 10 shows the resolution dependence of eight different ENX 13 EASY INT samples under following conditions: V_{cc}=5 V, 10‘000 rpm, 1 kΩ load, 25°C, non-binary resolution

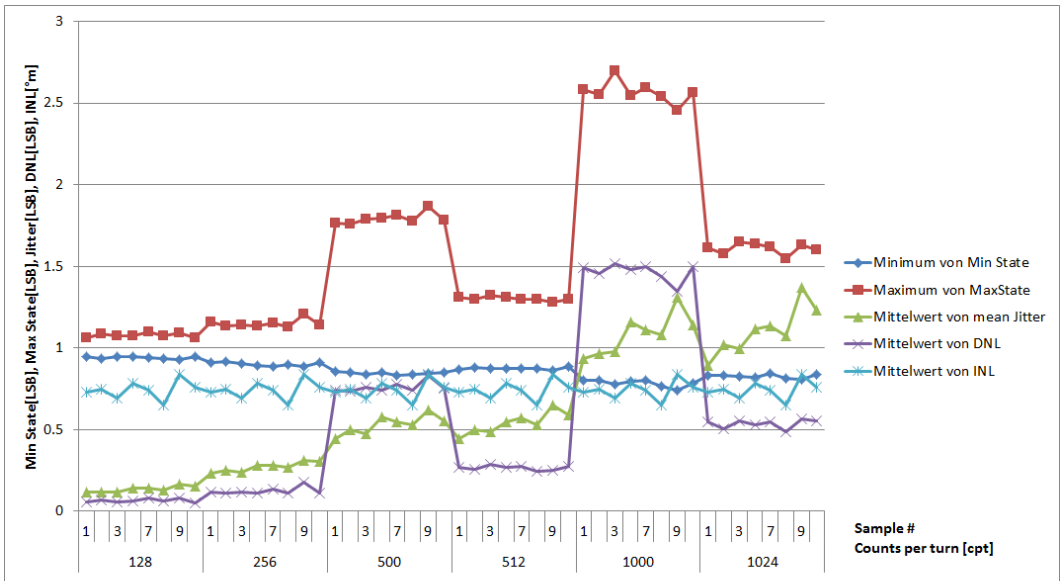


Figure 10 Resolution Dependence (Comparison binary/non-binary Resolutions)

5 PIN ASSIGNMENT

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

5.1 ENX 13 | 16 | 19 | 22 EASY INT COMM

Versions available:
- *Encoder with plug / Hall sensors without plug / Motor without plug*
- *Encoder with plug / Hall sensors with plug / Motor with plug (➔Figure 11)*

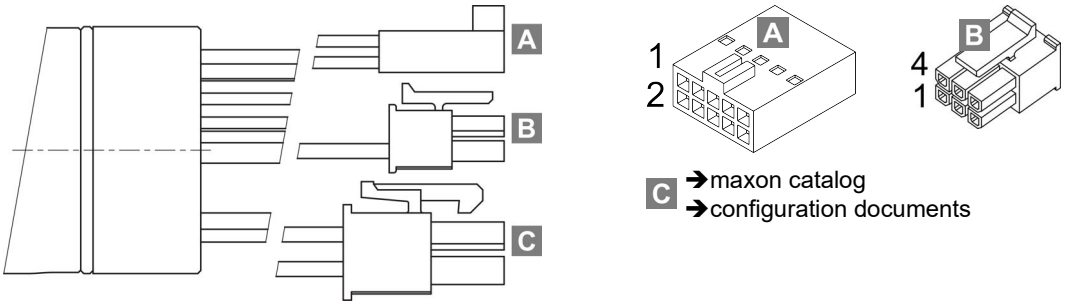


Figure 11 ENX 13 | 16 | 19 | 22 EASY INT COMM – Cable Plugs

Pin	Color	Signal	Description
A1	—	not connected	—
A2	black	V_{cc}	Power supply voltage
A3	brown	GND	Ground
A4	—	not connected	—
A5	red	ChA/	Channel A complement
A6	orange	ChA	Channel A
A7	yellow	ChB/	Channel B complement
A8	green	ChB	Channel B
A9	blue	ChI/	Channel I (index) complement
A10	violet	ChI	Channel I (Index)

Continued on next page.

Pin	Color	Signal	Description
B1	yellow	H1	Hall sensor 1
B2	brown	H2	Hall sensor 2
B3	gray	H3	Hall sensor 3
B4	—	not connected	—
B5	—	not connected	—
B6	—	not connected	—

Table 3 ENX 13 | 16 | 19 | 22 EASY INT COMM – Pin Assignment

Cable Plugs ENX 13…22 EASY INT COMM		
A	Connector	Crimp contact housing, 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)
B	Connector	Molex Micro-Fit 3.0, 6 poles (430-25-0600)
	Mating plug	Molex Micro-Fit 3.0, 6 poles (430-45-0612)
C	➔maxon catalog or configurations documents	

Table 4 ENX 13 | 16 | 19 | 22 EASY INT COMM – Specifications Cable Plugs

5.2 ENX 13 | 16 | 19 | 22 EASY INT Absolute

Versions available:
- *Absolute encoder without plug / Motor without plug*
- *Absolute encoder with plug / Motor with plug (➔Figure 12)*
- *Absolute encoder and motor with pins (➔Figure 13)*

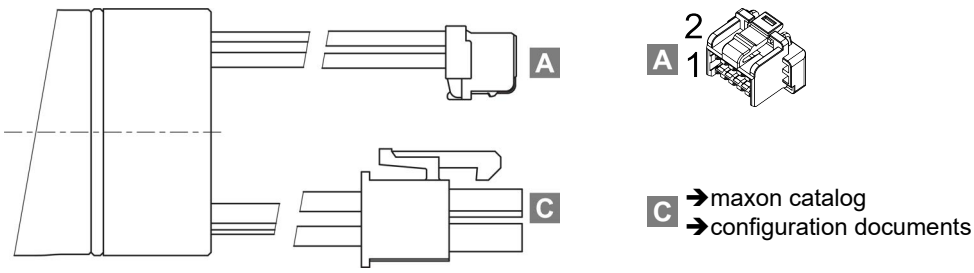


Figure 12 ENX 13 | 16 | 19 | 22 EASY INT Absolute – Cable Plugs

W1 / W2 / W3
Motor winding 1
Motor winding 2
Motor winding 3

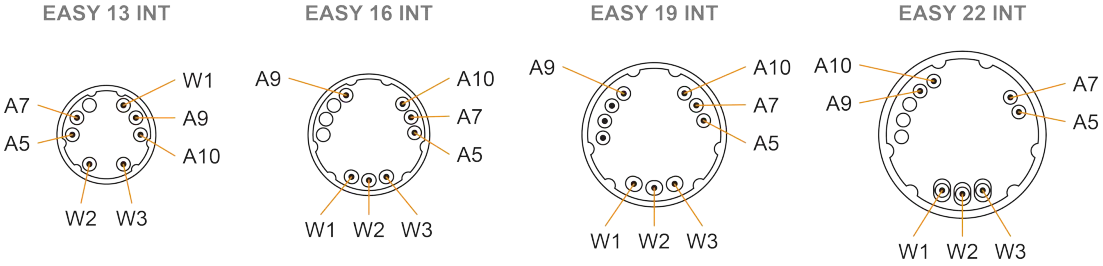


Figure 13 ENX 13 | 16 | 19 | 22 EASY INT Absolute – Pins

Continued on next page.

Pin	Color	Signal	Description
A1	—	not connected	—
A2	—	not connected	—
A3	—	not connected	—
A4	—	not connected	—
A5	yellow	SSI/BiSS CLK	Absolute encoder Clock
A6	—	not connected	—
A7	green	SSI/BiSS DATA	Absolute encoder Data
A8	—	not connected	—
A9	brown	GND	Ground
A10	black	V_{cc}	Power supply voltage

Table 5 ENX 13 | 16 | 19 | 22 EASY INT Absolute – Pin Assignment

Cable Plugs ENX 13…22 EASY INT Absolute		
A	Connector	Molex CLIK-Mate, pitch 1.5 mm, 5 x 2 poles (503149 series)
	Mating plug	Molex CLIK-Mate, pitch 1.5 mm, 5 x 2 poles (503154 series)
C	➔maxon catalog or configurations documents	

Table 6 ENX 13 | 16 | 19 | 22 EASY INT Absolute – Specifications Cable Plugs

5.3 ENX 16 | 19 | 22 EASY INT Absolute COMM

Versions available:
- *Absolute encoder, Hall sensors, and motor with pins (➔Figure 14)*

W1 / W2 / W3
Motor winding 1
Motor winding 2
Motor winding 3

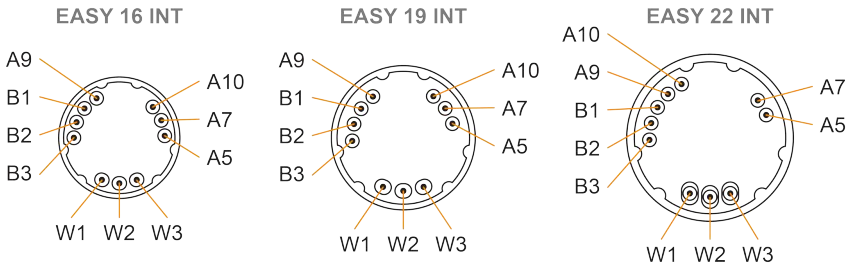


Figure 14 ENX 16 | 19 | 22 EASY INT Absolute COMM – Pins

Continued on next page.

Pin	Color	Signal	Description
A5	—	SSI/BiSS CLK	Data output absolute encoder Clock
A7	—	SSI/BiSS DATA	Data output absolute encoder Data
A9	—	GND	Ground
A10	—	V_{cc}	Power supply voltage
B1	—	H1	Hall sensor 1
B2	—	H2	Hall sensor 2
B3	—	H3	Hall sensor 3

Table 7 ENX 16 | 19 | 22 EASY INT Absolute COMM – Pin Assignment

5.4 ENX 13 | 16 | 22 COMM

Versions available:
- *Hall sensors without plug / Motor without plug*
- *Hall sensors without plug / Motor without plug / NTC without plug*
- *Hall sensors with plug / Motor with plug (➔Figure 15)*
- *Hall sensors with plug / Motor with plug / NTC with plug (➔Figure 16)*
- *Hall sensors, motor, and NTC with pins (➔Figure 17)*

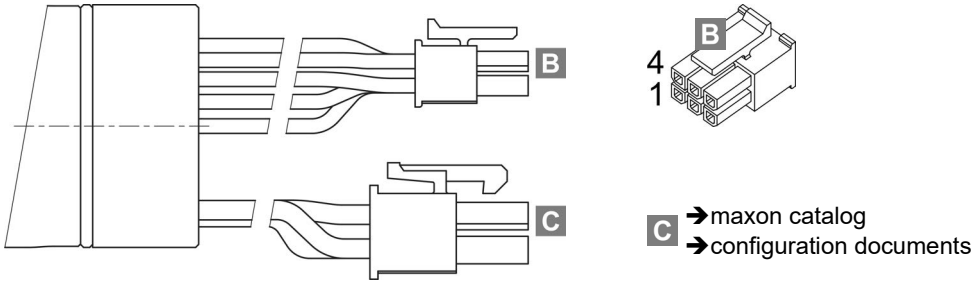


Figure 15 ENX 13 | 16 | 22 COMM – Cable Plugs

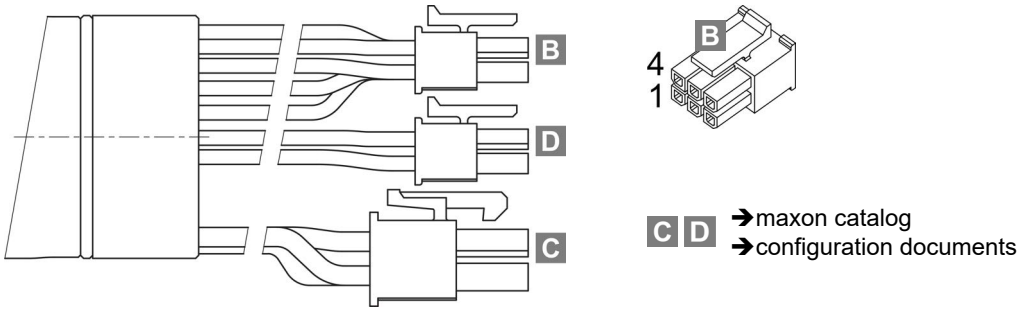


Figure 16 ENX 16 | 22 COMM (thermistor version) – Cable Plugs

Continued on next page.

W1 / W2 / W3
Motor winding 1
Motor winding 2
Motor winding 3

NTC1 / NTC2
Thermistor 1
Thermistor 2

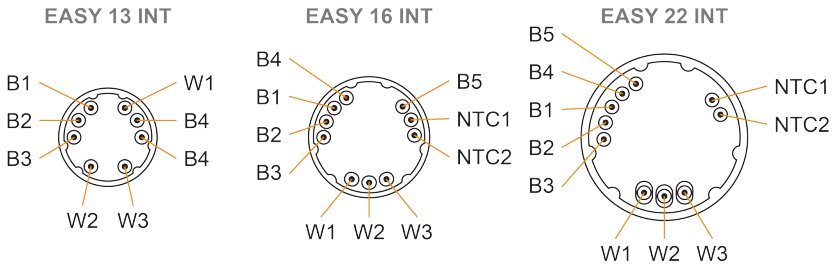


Figure 17 ENX 13 | 16 | 22 COMM – Pins

Pin	Color	Signal	Description
B1	yellow	H1	Hall sensor 1
B2	brown	H2	Hall sensor 2
B3	gray	H3	Hall sensor 3
B4	blue	GND	Ground
B5	orange	V_{Hall}	Hall sensor supply voltage
B6	—	not connected	—

Table 8 ENX 13 | 16 | 22 COMM – Pin Assignment

Cable Plugs ENX 13…22 COMM		
B	Connector	Molex Micro-Fit 3.0, 6 poles (430-25-0600)
	Mating plug	Molex Micro-Fit 3.0, 6 poles (430-45-0612)
C	➔maxon catalog or configurations documents	
D		

Table 9 ENX 13 | 16 | 22 COMM – Specifications Cable Plugs

6 OUTPUT CIRCUITRY

The following figures show the conceptual output schematics of the different encoders including ESD protection circuitry.

6.1 ENX 13 | 16 | 19 | 22 EASY INT COMM

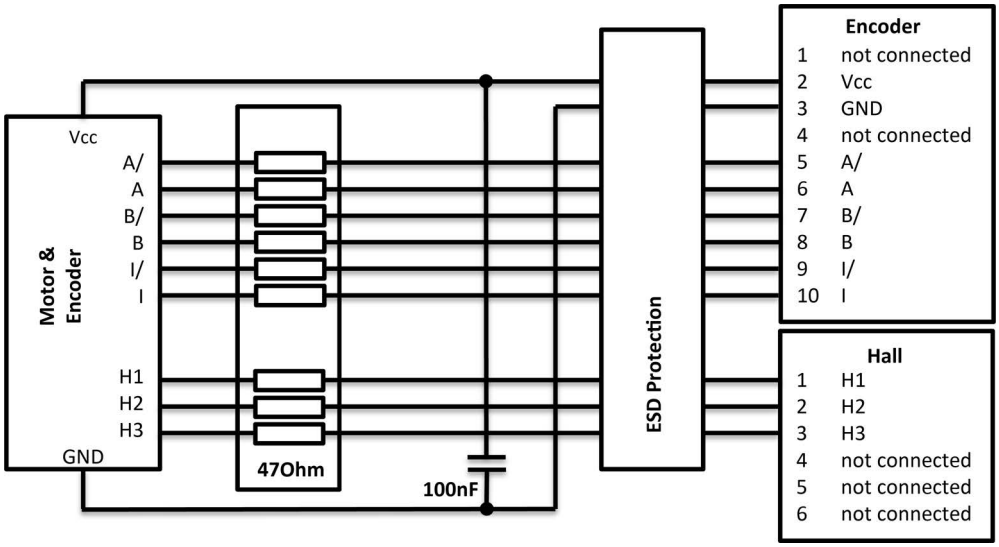


Figure 18 ENX 13 | 16 | 19 | 22 EASY INT COMM – Output Circuitry

6.2 ENX 13 | 16 | 19 | 22 EASY INT Absolute

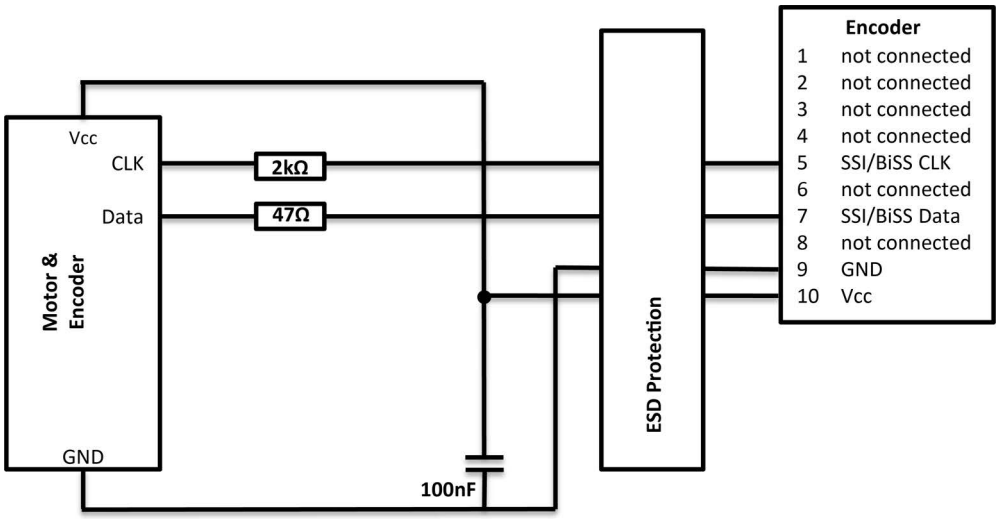


Figure 19 ENX 13 | 16 | 19 | 22 EASY INT Absolute – Output Circuitry

6.3 ENX 16 | 19 | 22 EASY INT Absolute COMM

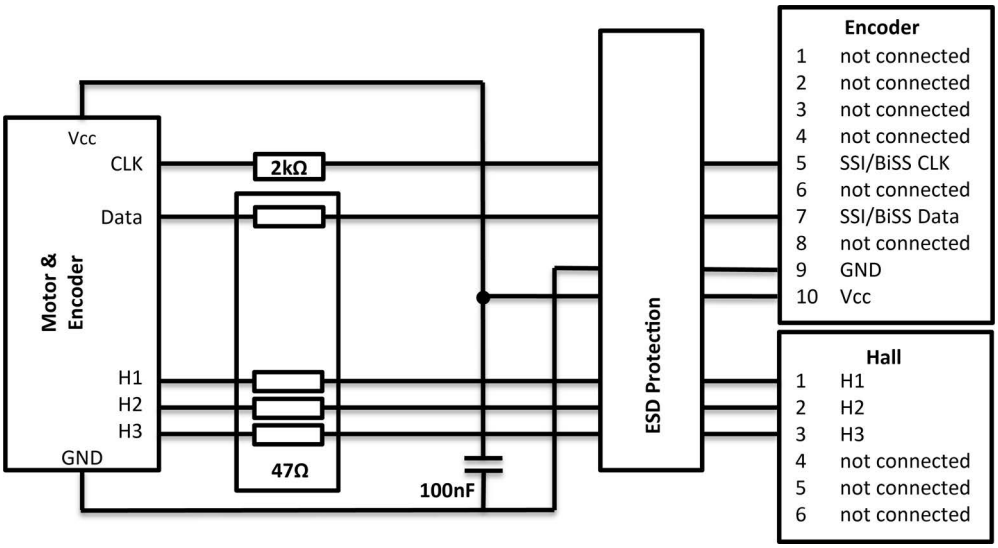


Figure 20 ENX 16 | 19 | 22 EASY INT Absolute COMM – Output Circuitry

6.4 ENX 13 | 16 | 22 COMM

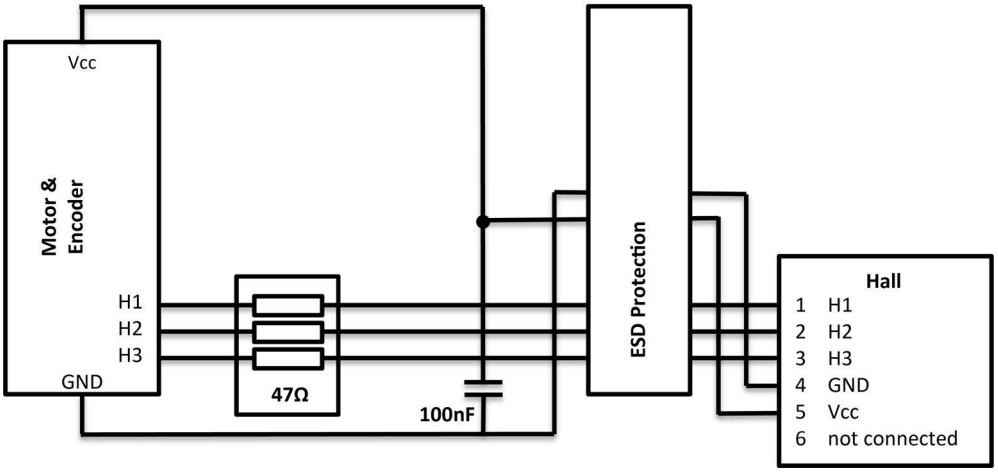


Figure 21 ENX 13 | 16 | 22 COMM – Output Circuitry

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