maxon

ENX MAG

Product Information

ENX MAG Encoders
Product Information
mmag | Edition 2024-04 | Document ID 4065222-04

maxon

TABLE OF CONTENTS

maxon

ENX MAG Encoders – Product Information

Figure 1 ENX 4 MAG / ENX 6 MAG / ENX 8 MAG / ENX 10 MAG INT (top down)

The ultra compact maxon MAG encoders use an interpolated Hall sensor angle measurement system to generate incremental quadrature output signals. They offer three channels (A, B, I) and are available with up to 256 impulses per turn. For the use with EC motors (BLDC, DC brushless), also commutation signals are generated.

With their reduced supply voltage of 3.3 V and low power requirements, the encoders are superbly suitable for mobile and battery-powered applications.

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})	ENX 4...8 MAG	–0.5	+4.6	V
	ENX 10 MAG	–0.5	+6	V
Voltage at signal output (V_{signal})		–0.5	+4.6	V
Operating temperature (T_{amb})		–40	+125	°C
Storage temperature (T_{store})		–40	+125	°C
Humidity (condensation not permitted)	ENX 4...8 MAG	20	80	%rH
	ENX 10 MAG	20	100	

1.2 General Data

Parameter	Conditions	Min	Typ	Max	Unit
Supply voltage (V_{cc})	ENX 4...8 MAG	+3	3.3	+3.6	V
	ENX 10 MAG	+3.3	5	+6	V
Supply current (I_{dd})	V_{cc} = 3.3 V, outputs unloaded		13		mA
Power-up time				2.5	ms

1.3 Incremental Interface

Parameter	Conditions	Min	Typ	Max	Unit
Number of channels	ChA, ChB, ChI		3		–
Counts per turn (N)	1…256, factory-configurable	1		256	cpt
Pulse frequency (f_{pulse})	Maximum output pulse frequency		500		kHz
Signal output current (I_{signal})		–4		+4	mA
Signal voltage high (V_{high}) I_{signal} <4 mA, relative to V_{cc}	ENX 4...8 MAG	V_{cc}–0.5 V			V
	ENX 10 MAG	3.1	3.3	3.5	V
Signal voltage low (V_{low})	I_{signal} <4 mA			0.5	V
Transition time (t_{trans})	Rise time/fall time ChA/B/I without load		15		ns

1.4 Commutation Interface

Parameter	Conditions	Min	Typ	Max	Unit
Number of channels	H1, H2, H3		3		–
Pulse frequency (f_{pulse})	Maximum output pulse frequency		20		kHz
Signal output current (I_{signal})		–4		+4	mA
Signal voltage high (V_{high}) I_{signal} <4 mA, relative to V_{cc}	ENX 4...8 MAG	V_{cc}–0.5 V			V
	ENX 10 MAG	3.1	3.3	3.5	V
Signal voltage low (V_{low})	I_{signal} <4 mA			0.5	V
Transition time (t_{trans})	Rise time/fall time ChA/B/I without load		15		ns

1.5 Angle Measurement

Conditions
All values at T = 25°C, n = 10000 rpm, V_{cc} = 3.3 V unless otherwise specified.

Definitions
See ➔Page 8.

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 commutation signals (Dir)	Motor shaft movement for signal phase alignment “H1 leads H2 leads H3” as seen from the shaft end		CW		
State length (L_{state}) and index pulse width (L_{index} synchronized with ChA/B), incremental signals	N=256 cpt	80	90	100	°e
Minimum state duration (t_{state})			62.5		ns
Integral Nonlinearity (INL), incremental signals	All number of impulses		2	5	°m
Integral Nonlinearity (INL), commutation signals			2		°m
Differential Nonlinearity (DNL)	N=64 cpt		0.01	0.03	LSB
	N=128 cpt		0.03	0.05	
	N=256 cpt		0.05	0.1	
Repeatability (Jitter), incremental signals	N=64 cpt		0.2	0.25	LSB
	N=128 cpt		0.5	0.75	
	N=256 cpt		1	1.5	
Repeatability (Jitter)	All number of impulses			0.5	°m
Phase delay A to B (Phase θ), incremental signals	All number of impulses	80	90	100	°e
Angle hysteresis (Hyst)			0.7		°m
Delay of digital signal path	Typical latency of digital signal processing		8		µs
Maximum commutation angle error (maxCAE)			4		°e

Preconditions for trouble-free operation

- *The encoder must be powered before turning the motor. Thereby, consider a power-up time of max. 2.5 ms.*
- *Due to the physical influence of rotor magnets and control magnets, torque fluctuations can occur in combination with small motors. These have an effect on the measured INL at low speed (<5000 rpm) in the unregulated mode.*
- *The encoder already reacts to small and medium magnetic interference fields (amplitude >1.5 mT). For best performance, the absence of magnetic fields in the immediate vicinity of the encoder is required.*
- *Voltage ripples (V_{pp}) in the supply voltage (V_{cc}) with an amplitude ≥0.15 V affect the repeatability of the encoder.*

1.6 Mechanical Data

Parameter	Conditions	Value	Unit
Dimensions (D x L), without flange (➔Chapter “1.6.1 Dimensional Drawing” on page de-6) [a]	ENX 4 MAG	Ø4.0 x 6.25	mm
	ENX 6 MAG	Ø6.0 x 6.1	
	ENX 8 MAG	Ø8.0 x 5.8	
	ENX 10 MAG INT	Ø10.0 x 4.25	
Moment of inertia (Jt)		0.0015	g cm^2
Standard cable length (Lc)	ENX 4 MAG	50	mm
	ENX 6 MAG	80	
	ENX 8 MAG	80	
	ENX 10 MAG INT	83	

[a] The effective length of the encoder housing is specified. The additional length of the encoder may be slightly longer (additional intermediate plate) or slightly shorter (depending on the motor to which the encoder is linked). Mounting the MAG encoders to the ECX motors results in only a little or no additional length, as the encoder PCB is largely or totally integrated into the motor.

Table 1 Technical Data

1.6.1 Dimensional Drawing

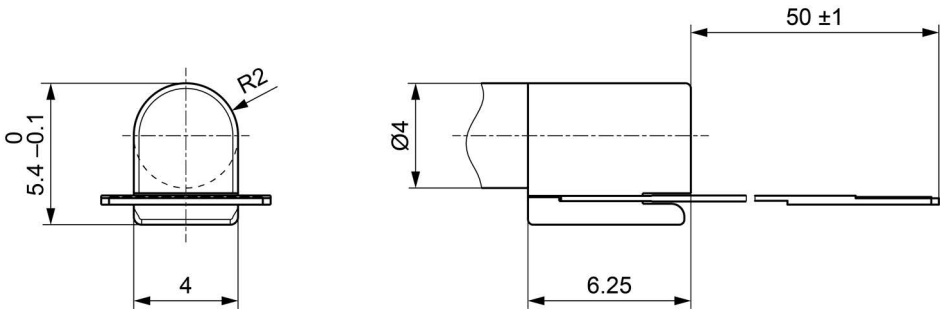


Figure 2 Dimensional Drawing [mm] – ENX 4 MAG

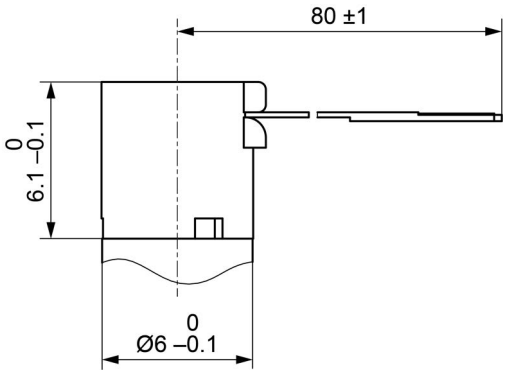


Figure 3 Dimensional Drawing [mm] – ENX 6 MAG

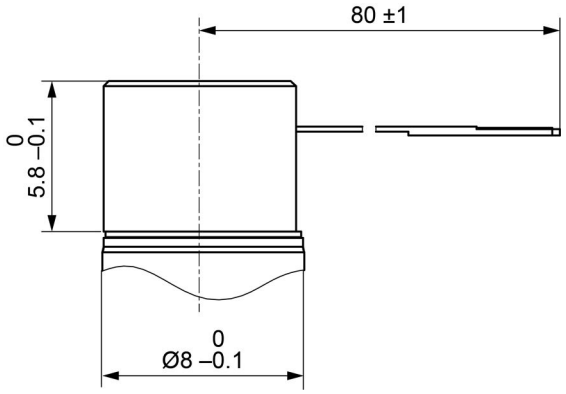
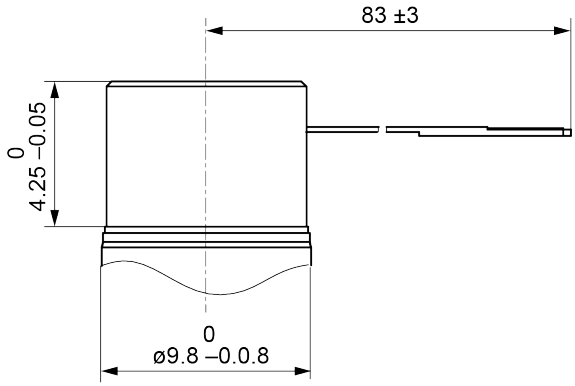


Figure 4 Dimensional Drawing [mm] – ENX 8 MAG



Dimensional Drawing [mm] – ENX 10 MAG INT

1.7 Angle Alignment

The index of the incremental encoder and rising edge of the commutation signal H1 is factory-programmed to the commutation angle “Zero” of the used EC (BLCD) motors (➔Figure 5 and Figure 7).

Mounted to a motor with several pole pairs (n), the incremental encoder presents the index once per mechanical turn. Based on the multiple pole pairs, the motor presents this commutation angle n times per mechanical turn.

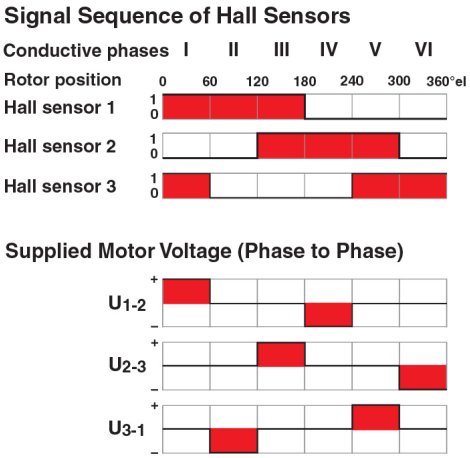
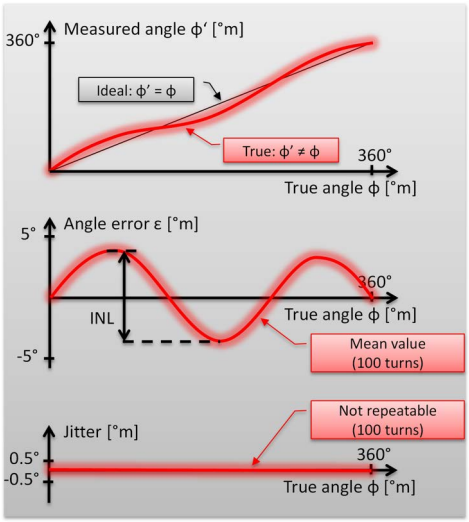
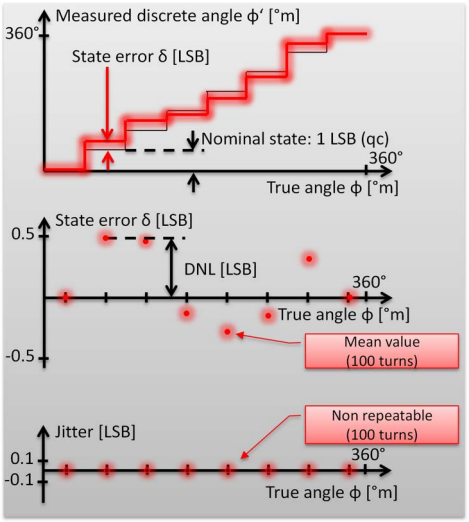
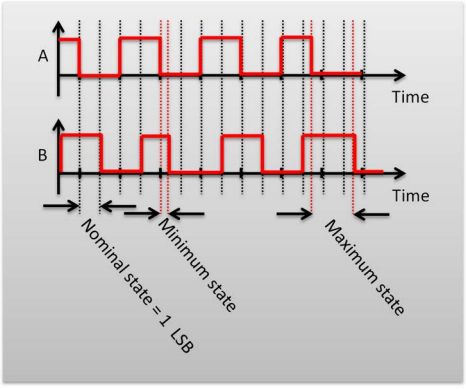


Figure 5 Block Commutation of EC (BLDC) Motors – Definition of Phases

2 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.	

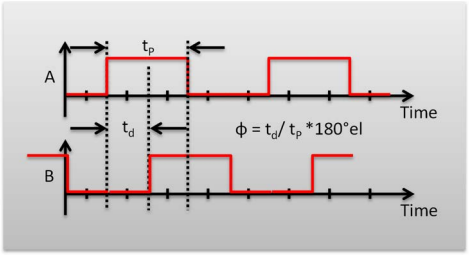
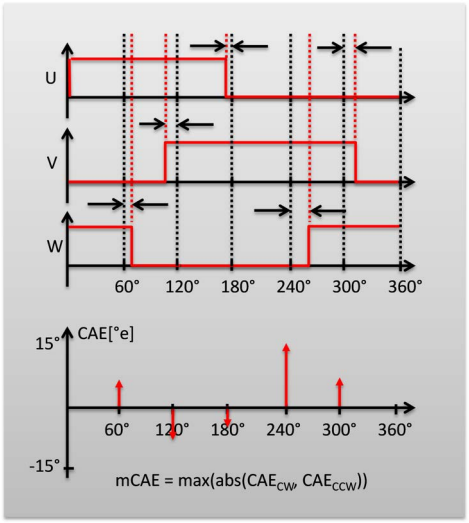
Metric	Definition	Illustration
Phase delay θ [°e]	Time difference of rising edge A to B relative to duration of positive level of A.	
Maximum commutation angle error (maxCAE) [°e]	Minimum positive or negative deviation of the individual switching points of the commutation signals (reference signals),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

Table 2 Definitions

3 TYPICAL MEASUREMENT RESULTS

3.1 Angle Error per Turn

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 three different MAG encoders configured in various resolutions under following conditions: Measurement of 25 turns at V_{cc}=3.3 V, n=10000 rpm, T=25°C.

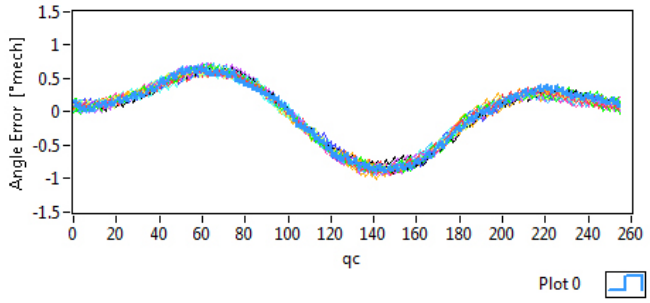
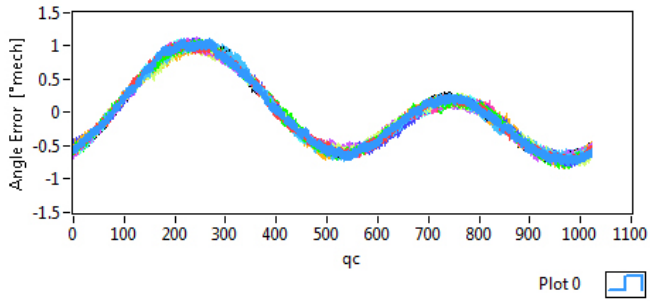
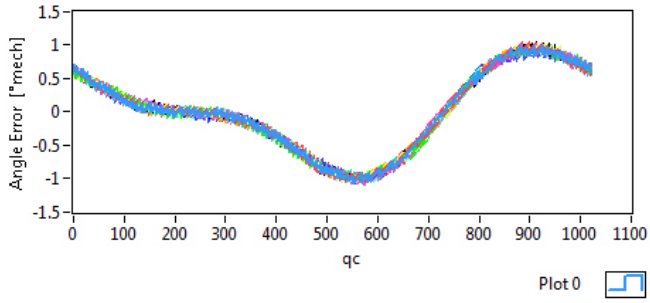
Resolution	Graph	Analysis	
64 cpt		INL Jitter DNL Min State Max State	1.6°m 0.2°m = 0.15 LSB 0.02 LSB 0.98 LSB = 88°e 1.02 LSB = 92°e
128 cpt		INL Jitter DNL Min State Max State	1.9°m 0.3°m = 0.4 LSB 0.03 LSB 0.97 LSB = 87°e 1.03 LSB = 93°e
256 cpt		INL Jitter DNL Min State Max State	1.9°m 0.2°m = 0.6 LSB 0.05 LSB 0.95 LSB = 85°e 1.05 LSB = 95°e

Table 3 Typical Measurement Results

3.2 Temperature Dependence

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 6 shows the temperature dependence of ten ENX 8 MAG under following conditions: V_{cc}=3.3 V, 10‘000 rpm, 256 cpt

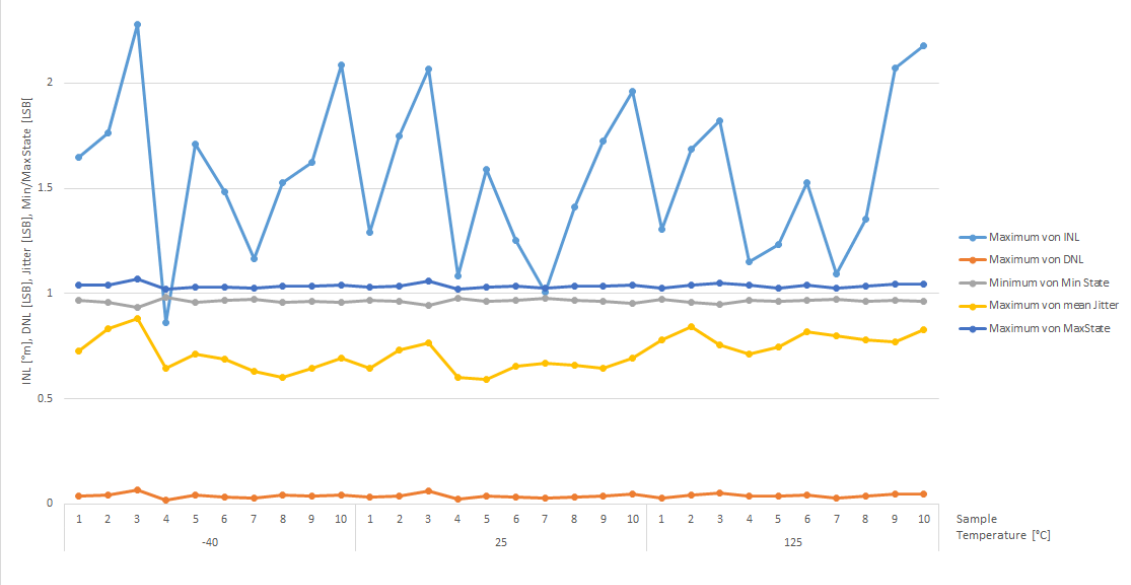


Figure 6 Temperature Dependence

3.3 Oscilloscope Plots

Figure 7 shows the incremental signals A, B, I with the commutation signal H1 recorded in rotational direction CW at V_{cc}=3.3 V, 20‘000 rpm, T=25°C.

Signals: C1 = ChA; C2 = ChB; C3 = ChI; C4 = H1; 5 us/div; 5 V/div

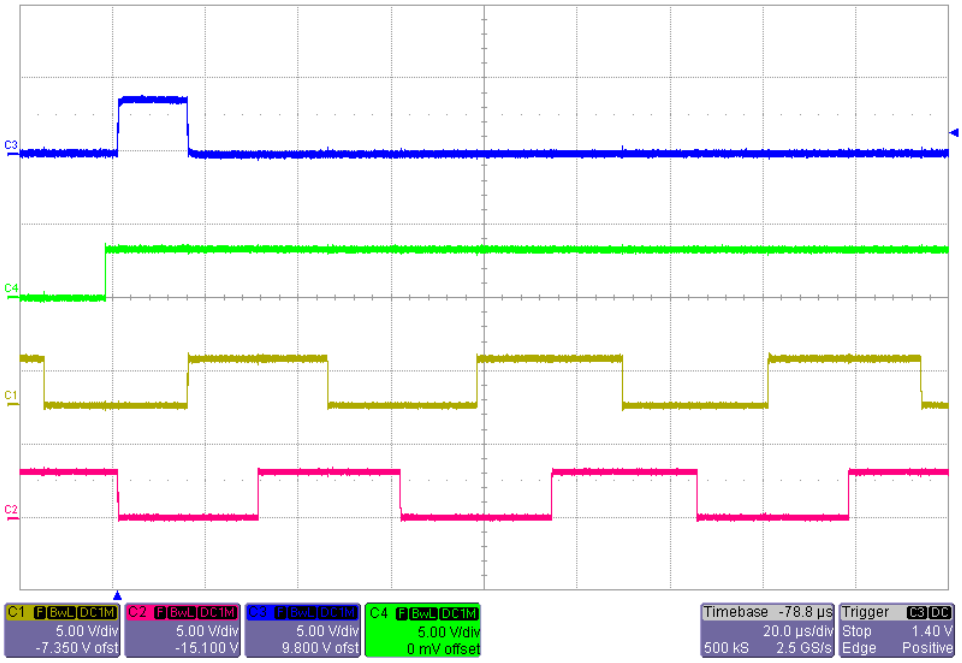


Figure 7 Oscilloscope plot 1

Figure 8 shows the commutation signal H1, H2, H3 with the incremental signal I recorded in rotational direction CW at V_{cc}=3.3 V, n=25000 rpm, T=25°C.

Signals: C1 = H2; C2 = H3; C3 = ChI; C4 = H1; 500 us/div; 5 V/div

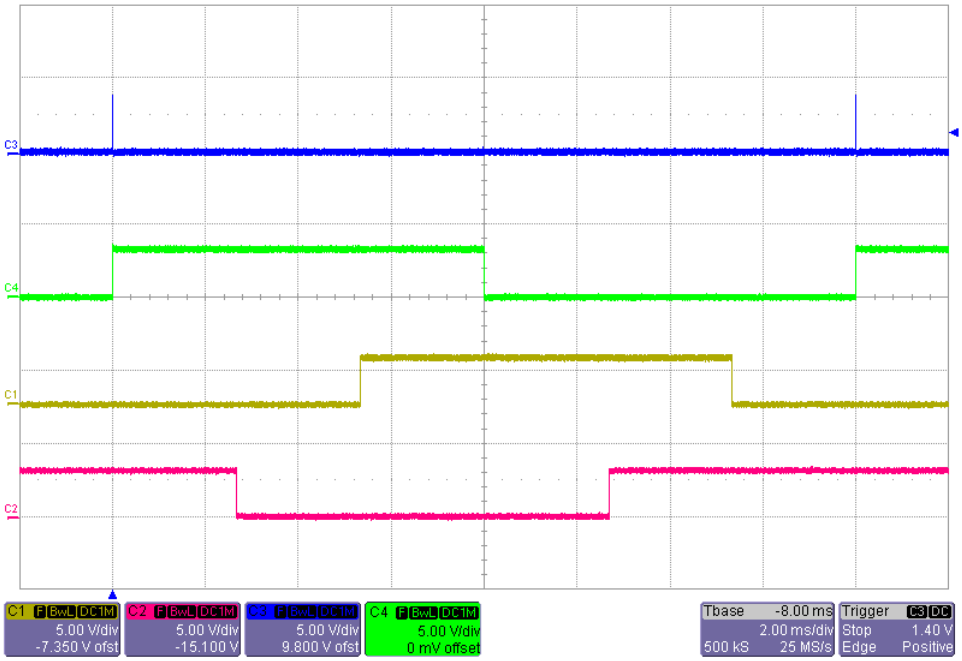
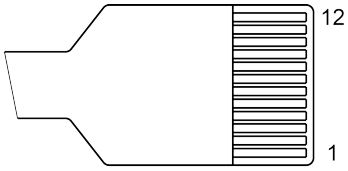


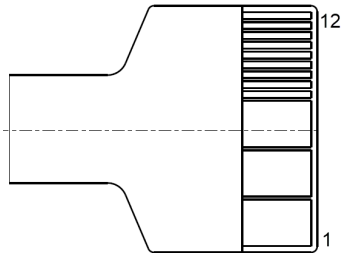
Figure 8 Oscilloscope plot 2

4 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).*



ENX 4 / 6 / 8 MAG



ENX 10 MAG INT

Figure 9 Connector

Pin	ENX MAG & DC motor	ENX MAG & EC motor with Hall sensors	Description
1	Motor +	Winding W1	Motor connections (maximum permissible motor current, ➔ see Table 5)
2	Motor −	Winding W2	
3	not connected	Winding W3	
4	GND	GND	Ground
5	V_{cc}	V_{cc}	Power supply voltage
6	ChA	ChA	Channel A
7	ChB	ChB	Channel B
8	ChI	ChI	Channel I (Index)
9	do not connect	H1	Commutation signal U
10	do not connect	H2	Commutation signal V
11	do not connect	H3	Commutation signal W
12	do not connect	do not connect	

Table 4 Connector – Pin Assignment

Specifications		
Type	**Permitted continuous current Pin 1, 2, 3**	**Mating plug**
ENX 4 MAG ENX 6 MAG ENX 8 MAG	≤ 0.5 A	FFC/FPC connector; for example… • Molex (52745-1297) • TE (1-1734839-2)
ENX 10 MAG INT	≤ 2.5 A	• Molex (52207-2460)

Table 5 Connector – Specifications

5 OUTPUT CIRCUITRY

Figure 10 shows the conceptual output schematic.

Figure 10 Output Circuitry – ENX MAG

In general, a high-impedance network (CMOS input, for example) is recommended.

Pull-up and/or pull-down resistors are permitted but not necessary. However, if they are used, they must be dimensioned that the current per channel is limited to <4 mA (R>820 Ω @ V_{ENC} = 3.3 V).

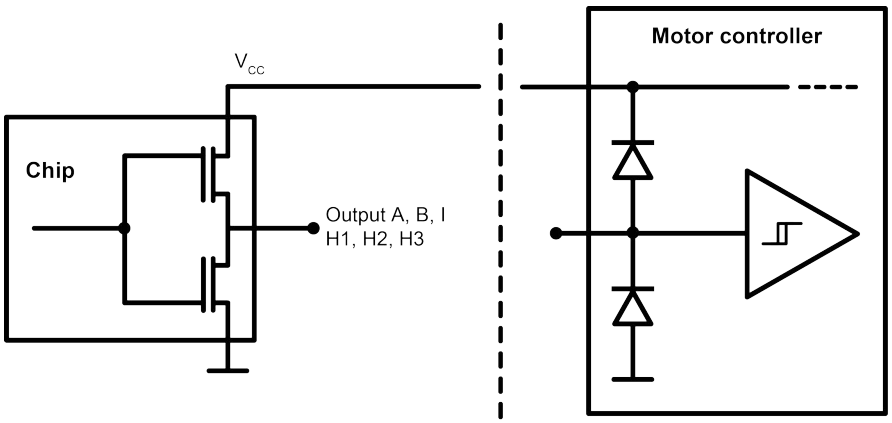


Figure 11 Output Circuitry

Supply Voltage
The supply voltage of the load network must not exceed the supply voltage of the encoder.

6 ACCESSORIES

Order number	Description	
498157	Adapter ENX 4 MAG ENX 6 MAG ENX 8 MAG	For connecting the ENX 4/6/8 MAG with integrated motor cables to a maxon controller. Adapter from flexprint connectors to screw terminals and pin headers. With integrated Line Driver RS422 and selectable encoder supply V_{ENC} = 3.3V (from V_{CC} via linear regulators) or $V_{ENC} = V_{CC}$ = 5 V
804420	Adapter ENX 10 MAG INT	To connect the ENX 10 MAG INT with integrated motor cables to a maxon controller. Adapter from flexprint connector to screw terminals.
For further details ➔maxon catalog		

Table 6 Suitable Accessories

maxon

mmag | ENX MAG Encoders Product Information | Edition 2024-04 | Document ID 4065222-04