

General technical data – Incremental encoders

Optical principle

All the WDG incremental encoders in this catalogue (except WDG24A/24C) are based on non-contact optical scanning. The light from a high-performance LED is parallel aligned by means of a lens and shines through a lens aperture disc and a pulse disc. The aperture disc is integrated in the flange. The pulse disc is mounted on the stainless-steel shaft that is free from backlash thanks to its special bearings. If the shaft is rotated, then the combination of aperture and pulse discs cause finely defined fields to open and close. Either light is let through the grid or not. This layout means two signals are detected, phase-shifted by 90°, as well as a zero (index) pulse. The difference between light and dark is detected by receiving transistors, working differentially, mounted on the PCB on the opposite side. From this the electronic circuitry preprocesses high-precision signals and then amplifies them into industrially usable pulse-forms, for example sinusoidal or square-wave, HTL or TTL and their inverted signals.

Our WDG encoders are finely-tuned measuring systems, made up of a combination of precision mechanics, a compact optical segment and high-performance electronics.

Optics

Light source: IR - LED
Service life: typ. 100,000 hours. WDG58T: 80.000 hours.
Scanning: differential

Magnetic principle

The WDG incremental encoders type 24A/C work on a non-contact magnetic scanning principle. A diametral magnetised magnet is mounted in the stainless-steel shaft with its backlash-free bearings. If the shaft is rotated, the magnet and the magnetic field rotate with it. This change in the magnetic field is detected and processed by a sensor chip on the PCB opposite. The evaluation enables signals to be generated that are 90° phase-shifted as well as a zero pulse. The downstream electronics conditions these into high-precision signals and amplifies them into industrially usable square-wave pulses in HTL and TTL plus their inverted signals.

Our WDG magnetic encoders are finely-tuned measuring systems, combining precision mechanics, efficient sensor technology and high-performance electronics.

Accuracy incremental encoders

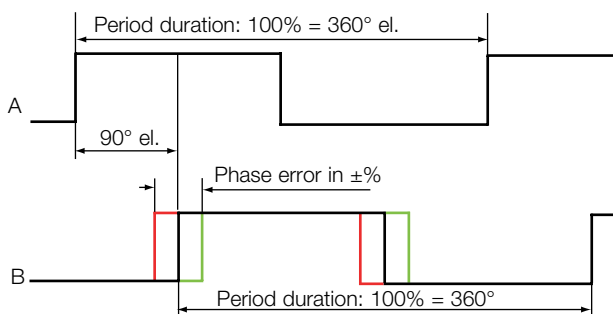
Shaft encoders have three defined types of accuracy. In each case the accuracy is given as a % of the pulse length, which consists of a pulse and a pause.

The partition error is defined as the deviation of any pulse edge from its exact geometric position and as standard is a max 12%.

The pulse/pause ratio describes the ratio of the pulse/pause deviation from the pulse length. The accuracy value has been given for each encoder and as standard amounts to a max ± 7.5%.

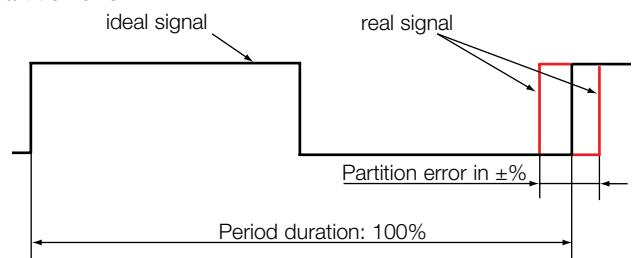
The phase displacement describes the accuracy of two successive edges. The accuracy is given for each encoder and as standard amounts to a max. 7.5% of a pulse length.

Phase offset:



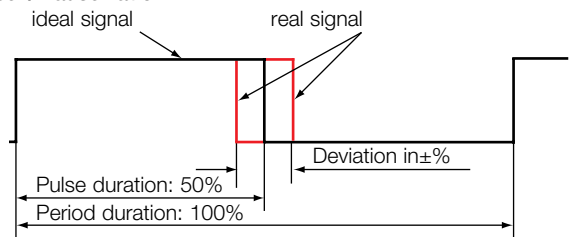
El. phase offset: 90° ± max. phase error 7,5% of a pulse length

Partition error:



Partition: max. 12%

Pulse-/Pause-ratio

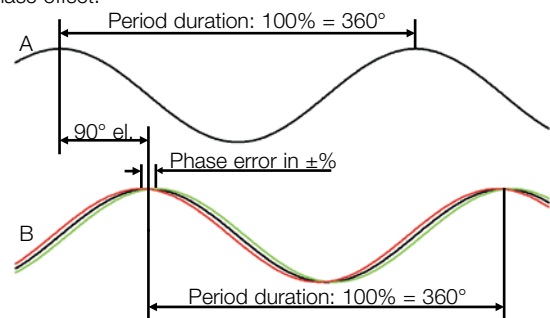


Pulse-/Pause-ratio: 50 % max. ± 7 %

(WDG24C: 1 PPR up to 128 PPR: 50 % max. ±10 %
256 PPR, 512 PPR, 1024 PPR: 50 % max. ±20 %)

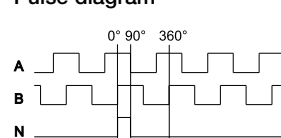
Accuracy sinus encoders

Phase offset:

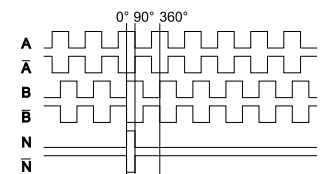


El. phase offset: 90° ± max. phase error 7,5% of a pulse length

Pulse diagram



G24, F24, H24, G05, F05,
H05, H30, N05, N24, N30

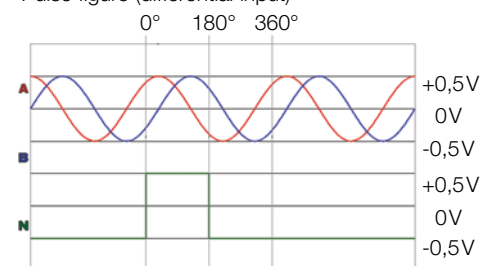


I24, R24, P24, I05, R05, M05, M24,
M30, P05, R30, 245, 524, 645

View from shaft end, rotating clockwise

SINUS

-Pulse figure (differential input)

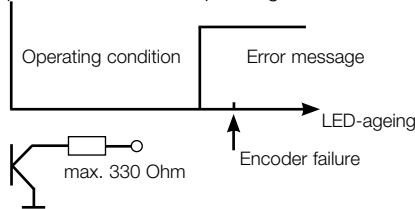


View from shaft end, rotating clockwise

Light reserve warning

For the purpose of preventive maintenance, WDG optical encoders that have the output circuits G24, G05, I24, I05, 524 and SIF (SIF only for WDG80H and WDG100H) are equipped with an early warning output. When the LED intensity drops to a level approximately 10 % of its original value, this output provides a warning of the impending failure of the encoder signals.

Nevertheless the optical encoder will continue to operate for more than 1000 hours and can thus be replaced during normal servicing. The early warning output conducts in the operating condition.



Output switching:

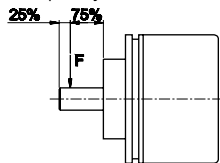
With light reserve warning: G05, G24, I05, I24, 524 (not for WDG40xx), SIF (SIF with light reserve warning only WDG80H and WDG100H)

Without light reserve warning:

F05, F24, H05, H24, N05, N24, N30, M05, M24, M30, P05, P24, R05, R24, R30, 245, 645, SIN

Mechanically rugged

All encoders have double and clearance-free shaft bearings with the maximum possible distance between the bearings, thus obtaining maximum long-term load capacity.



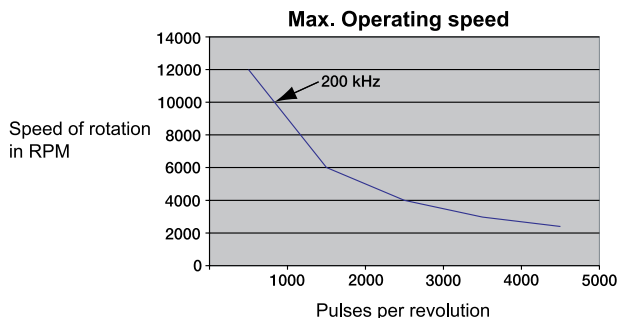
The bearings are treated with a special grease able to withstand extreme temperatures, high speeds and loads, as well as constant operation in reverse. The grease remains stable over a long period of time. The indicated radial-bearing load relates to the point F of the applied force. The useful life of the bearings is stated in the number of revolutions. The life can be converted into hours using the following formula:

$$\text{Life in hours} = \frac{\text{Number of Revolutions}}{(\text{RPM}) \cdot 60}$$

Maximum Operating Speeds

The maximum operating speed is limited by the maximum mechanical operating speed (shaft speed) and by the number of pulses per revolution (PPR). The maximum operating speed is given in the specifications. The maximum speed with relation to the pulse frequency can be expressed as follows:

$$\text{Max. speed of rotation RPM} = \frac{\text{Max. Frequency of encoder in Hz} \times 60}{\text{PPR of encoder}}$$



Maximum Output Frequency:

The maximum output frequency is given for the various encoders. For limiting factors such as cable lengths and diameters, please see the section on cable lengths. When designing the electronic evaluation circuitry for maximum frequencies and noise suppression, tolerances should be taken into account in order to provide a safety margin so as to handle maximum output frequencies which may occur in the specific

application. The maximum occurring frequency $f_{(max)}$ can be calculated using the following formula:

$$f_{inHz} = \frac{(\text{max shaft speed in RPM}) \times (\text{pulses per revolution PPR})}{60}$$

Maximum output frequency $f_{(max)}$ in relation to cable length and operating voltage at 25 °C and 20 mA load with our Wachendorff cable:

Output circuit	Power supply	G24/H24	I24/R24
		f_{aus}	f_{aus}
10 m	10-30 V	200 kHz	200 kHz
50 m	12 V	200 kHz	200 kHz
	24 V	200 kHz	100 kHz
	30 V	150 kHz	50 kHz
100 m	12 V	200 kHz	200 kHz
	24 V	200 kHz	50 kHz
	30 V	70 kHz	

Output circuit	Power supply	F24	P24
		f_{aus}	f_{aus}
10 m	12 V	560 kHz	450 kHz
	24 V	350 kHz	350 kHz
	30 V	280 kHz	280 kHz
50 m	12 V	250 kHz	200 kHz
	24 V	150 kHz	100 kHz
	30 V	100 kHz	50 kHz
100 m	12 V	300 kHz	150 kHz
	24 V	100 kHz	50 kHz

Output circuit	Power supply	G05/H05	I05/R05
		f_{aus}	f_{aus}
100 m	5 V	200 kHz	200 kHz

Output circuit	Power supply	F05	P05
		f_{aus}	f_{aus}
100 m	5 V	2 MHz	2 MHz

Output circuit	Power supply	245/524	645
		f_{aus}	f_{aus}
100 m	5 V	200 kHz	2 MHz

Output circuit	Power supply	M30/N30
		f_{aus}
25 m	5-30 V	200 kHz

Output circuit	Power supply	M05/N05
		f_{aus}
10 Meter	4,75-5,5 V	20 kHz

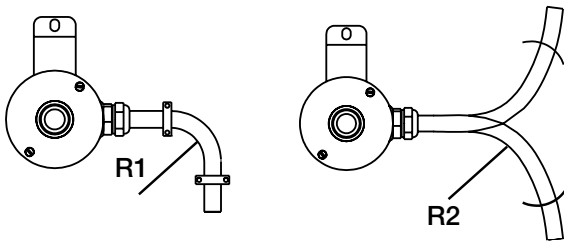
Output circuit	Power supply	M24/N24
		f_{aus}
10 m	10-30 V	20 kHz

Output circuit	Power supply	R30/H30
		f_{aus}
10 m	5-30 V	200 kHz
50 m	5 V	200 kHz
	12 V	155 kHz
	24 V	75 kHz
	30 V	58 kHz
100 m	5 V	200 kHz
	12 V	70 kHz
	24 V	30 kHz
	30 V	24 kHz

Connection safety:

All encoders with output circuits G24, H24, I24, R24, F24, P24, N24 and M24 are reverse polarity protected and can be wired in complete safety - it does not matter if the connections are reversed, even on a long-term basis. However with all other encoders, polarity reversal, a short-circuit of the outputs or applying voltage to the outputs can lead to failure of the encoder.

	Cable for encoders without low-temperature			Cable T3	Cable for encoders with low-temperature -40 °C up to +80 °C (-40 °F up to +176 °F)	
Encoder types	all encoder types except WDG 24, 40, 58T, 58S, 58V	WDG58S, WDG58V	WDG24C, WDG40, WDG58T	WDG58M	WDG40	WDG 50B, 53, 58, 70B, 80H, 100H, 115T, 115M
Core	stranded copper wire					
Cross-section for signal lines power lines	0.14 mm ² 0.34 mm ²	0.14 mm ² 0.34 mm ²	0.14 mm ² 0.14 mm ²	0.14 mm ² 0.14 mm ²	0.14 mm ² 0.14 mm ²	0.14 mm ² 0.34 mm ²
Cable cross-section	circuits: not inverted 6.3 mm inverted 8.3 mm	all circuits: 8.3 mm	circuits: WDG40 inverted: 7 mm all other circuits: 6 mm	all circuits: 6 mm	all circuits: 6.2 mm	all circuits: 8.3 mm
Shield	Tinned braided copper. Stranded filter wire for simple connection					
Outer sheath	light-grey PVC	light-grey TPE	light-grey PVC	black PVC	black PUR	light-grey TPE
Line resistance for 0.14 mm ² max.: for 0.34 mm ² max.:	148 Ohm/km 57 Ohm/km		148 Ohm/km	148 Ohm/km	148 Ohm/km	148 Ohm/km 57 Ohm/km
Operating capacity Core/Core: Core/shield:	140 nF/km approx. 155 nF/km			120 nF/km approx. 120 nF/km	140 nF/km approx. 155 nF/km	



Encoders without low-temperature

Cable Ø	R1	R2	Temperature
≤ 7 mm	31,5 mm	94,5 mm	T > -20 °C (-4 °F)
> 7 mm	41,5 mm	124,5 mm	T > -20 °C (-4 °F)

Encoders with low-temperature

Cable Ø	R1	R2	Temperature
≤ 7 mm	46,5 mm	139,5 mm	T > -40 °C (-40 °F)
> 7 mm	62,3 mm	186,9 mm	T > -40 °C (-40 °F)

Encoders with cable T3

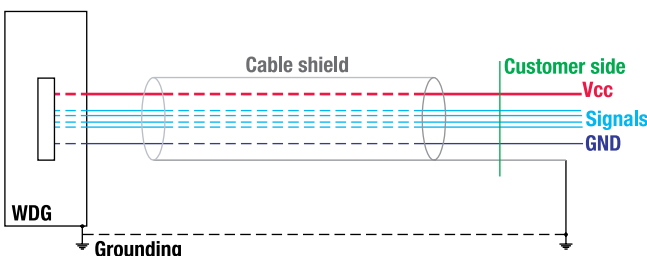
Cable Ø	R1	R2
6 mm	30 mm	90 mm
	T > -40 °C (-40 °F)	T > -10 °C (-14 °F)

Cable length:

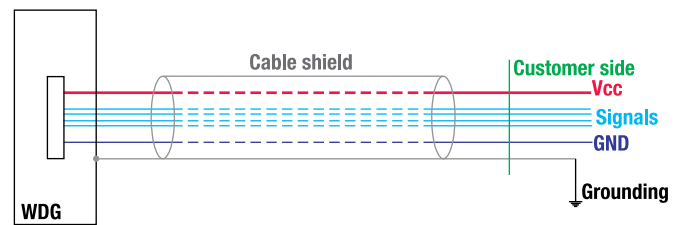
Using Wachendorff encoder cable a cable run of up to 100 m is possible (150 m for SINUS encoders). However the actual achievable cable length depends on the possible effects of noise interference and should therefore be checked for each individual case. Please refer to the tables regarding the max. output frequency depending on the cable length on page 2.

Typical shielding concepts for WDG encoders with cable outlet

K1, K2, K3: Screen separated at encoder.
Cable screening earthed on customer side
The encoder housing must be earthed separately.



L2/L3, T3: Cable shield connected to encoder housing.
Encoder housing not earthed separately.



Note:

In order to avoid compensating flows which will damage the ball bearing in an earth loop, earthing on both sides is not recommended.

Protection from Noise Interference

For efficient protection of the entire system we recommend the following measures:

For normal applications it is sufficient to connect the shield of the encoder cable to the earth potential. The entire system, consisting of the encoder and the signal processing equipment should be grounded at one single location by using a low resistance connection (e.g. braided copper).

- In all cases the connecting cables should be shielded and should be locally kept away from power lines and other noise-generating equipment.
- Sources of interference such as motors, solenoid valves, frequency converters etc should always have their noise suppressed at source.
- Encoders should not be powered from the same mains supply as solenoid valves or contactors, as this may cause interference.

In certain applications it may be necessary to install additional protection against interference, depending on the way the system is earthed and on the noise fields present. Such measures would include: capacitive coupling of the screen, the installation of HF- filters in the encoder cable or the installation of transient protection diodes. If these or any other measures are necessary, please contact us.

Environmental Data

Measured mounted and housing grounded.	
ESD (DIN EN 61000-4-2):	8 kV
Burst (DIN EN 61000-4-4):	2 kV
Vibration (IEC 68-2-6):	50m/s ² (10-2000 Hz)
Shock (IEC 68-2-27):	1000m/s ² (6 ms)
Design according to:	DIN VDE 0160

Connection configuration for cable and connector outlets:

On the following pages you will find our standard configuration for cable and connector outlets with regard to the corresponding output circuits. If you would like a special configuration to suit your application, please call Kai Nagel on Tel.: +49 (0) 67 22 / 99 65 77 or send him an e-mail at kn@wachendorff.de

Connection configuration for cable outlet:

	Cable									
Description	K1 radial			K2/L2 axial; K3/L3 radial; T3 tangential						
Circuit	F/H/05 F/H24 H30	245 R05 R24	R30	G05 G24	F/H05 F/H24 H30	I05 I24 524	P/R05 P/R24 245 645 R30 not WDG58S WDG58V	SIN WDG58 WDG63 WDG67 WDG70 WDG115	SIN WDG80H WDG100H	SIF WDG80H WDG100H
encoder type			WDG58T							
Minus U-	WH	WH	WH	WH	WH	WH	WH	WH	WH	WH
Plus U+	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN
A	GN	GN	GN	GN	GN	GN	GN	GN	GN	GN
B	YE	YE	YE	YE	YE	YE	YE	GY	GY	GY
N	GY	GY	GY	GY	GY	GY	GY	-	BK	BK
Light reserve warning	-	-	-	PK	-	PK	-	-	-	RD
A inv.	-	RD	RD	-	-	RD	RD	YE	YE	YE
B inv.	-	BK	PK	-	-	BK	BK	PK	PK	PK
N inv.	-	VT	BU	-	-	VT	VT	-	VT	VT
Shield	Litze									
	Shield not connected to encoder housing			Shield connected to encoder housing (only L2, L3, T3)						

**Special cable configuration for cable outlet
Encoder WDG58S, WDG58V:**

	Cable				
Description	K2, L2 axial; K3, L3 radial				L2 axial; L3 radial
Circuit	G05 G24	F/H05 F/H24 H30	I05 I24 524	P/R05 P/R24 245 645 R30	SIN
Minus U-	WH	WH	WH	WH	WH
Plus U+	BN	BN	BN	BN	BN
A	GN	GN	GN	GN	GN
B	YE	YE	YE	YE	GY
N	GY	GY	GY	GY	-
Light reserve warning	PK	-	PK	-	-
A inv.	-	-	RD	RD	YE
B inv.	-	-	BU	BU	PK
N inv.	-	-	VT	VT	-
Shield	Litze				
	Shield connected to encoder housing (only L2, L3)				

**Special cable configuration for cable outlet
Encoder WDG24C:**

	Cable	
Description	K7/L7 radial	
Circuit	N05 N24 N30	M05 M24 M30
Minus U-	WH	WH
Plus U+	BN	BN
A	GN	GN
B	YE	YE
N	GY	GY
Light reserve warning	-	-
A inv.	-	RD
B inv.	-	PK
N inv.	-	BU
Shield	Litze	
	Shield connected to encoder housing (only L7)	

Abbreviations for cable colours

BK = black
 BN = brown
 BU = blue
 GD = gold
 GN = green
 GY = grey
 PK = pink
 RD = red
 SR = silver
 TQ = turquoise
 OG = orange
 VT = violet
 WH = white
 YE = yellow

Pin assignment connector SI/SH (M16x0,75), 5-, 6-, 8-, 12-pin:

Type	M16x0,75												
Bezeichnung	SI5 axial, SH5 radial, 5-pin			SI6 axial, SH6 radial, 6-pin			SI8 axial, SH8 radial, 8-pin			SI12 axial, SH12 radial, 12-pin			
Circuit	F/H05 F/H24 H30	G05 G24	F/H05 F/H24 H30	F/H05 F/H24 H30	P/R05 P/R24 R30, 245, 645, SIN SIN only WDG80H WDG100H	SIN WDG58 WDG63 WDG67 WDG70 WDG115	G05 G24	F/H05 F/H24 H30	I05 I24 524	P/R05 P/R24 245 645 R30	SIN WDG58 WDG63 WDG67 WDG70 WDG115	SIN WDG80H WDG100H	SIF WDG80H WDG100H
encoder type													
Minus U-	1	6	6	1	1	1	K / L	K / L	K / L	K / L	K / L	K / L	K / L
Plus U+	2	1	1	2	2	2	M / B	M / B	M / B	M / B	M / B	M / B	M / B
A	3	2	2	3	3	3	E	E	E	E	E	E	E
B	4	4	4	4	4	4	H	H	H	H	H	H	H
N	5	3	3	5	5	-	C	C	C	C	-	C	C
Light reserve warning	-	5	-	-	-	-	G	-	G	-	-	-	G
A inv.	-	-	-	-	6	6	-	-	F	F	F	F	F
B inv.	-	-	-	-	7	7	-	-	A	A	A	A	A
N inv.	-	-	-	-	8	-	-	-	D	D	-	D	D
n. c.	-	-	-	6, 7, 8	-	-	A, D, F, J	A, D, F, G, J	J	G, J	D, G, J	G, J	J
Shield	-	-	-	-	-	-	-	-	-	-	-	-	-

Connector connected to encoder housing

Accessories

IP40		KD-5-40	-	KD-8-40, KD-8-40-SIN	-
IP40		-	-	-	-
IP65		-	-	-	-
IP67		-	-	KD-8-67 (not SIN)	KD-SH12-67 (not Sinus/Cosinus)
IP67		-	KDA-6-67	KDA-8-67 (not SIN)	-

Pin assignment connector S2/S3 (M16x0,75), 7-pin; connector S4/S5 (M23), 12-pin; MIL-connector, 6-pin; Valve-connector, 4-pin:

Type	M16x0,75		M23							MIL		Valve
Description	S2 axial, S3 radial, 7-pin		S4 axial, S4R axial, S5 radial, S5R radial, 12-pin							S6 radial, 6-pin		S7 axial, 4-pin
Circuit	G05 G24	F/H05 F/H24 H30	G05 G24	F/H05 F/H24 H30	I05 I24 524	P/R05 P/R24 245 645 R30	SIN WDG58 WDG63 WDG67 WDG70 WDG115	SIN WDG80H WDG100H	SIF WDG80H WDG100H	G05 G24	F/H05 F/H24 H30	F/H05 F/H24 H30
encoder type												
Minus U-	1	1	10	10	10	10	10	10	10	A	A	1
Plus U+	2	2	12	12	12	12	12	12	12	F	F	2
A	3	3	5	5	5	5	5	12	5	C	C	3
B	4	4	8	8	8	8	8	8	8	B	B	4
N	5	5	3	3	3	3	-	3	3	D	D	-
Light reserve warning	6	-	11	-	11	-	-	-	7	E	-	-
A inv.	-	-	-	-	6	6	6	6	6	-	-	-
B inv.	-	-	-	-	1	1	1	1	1	-	-	-
N inv.	-	-	-	-	4	4	-	4	4	-	-	-
n. c.	7	-	7	6, 7, 8	2, 7, 9	2, 7, 9, 11	2, 3, 4, 7, 9, 11	2, 7, 9, 11	2, 9, 11	-	E	-
Shield	-	-	-	-	-	-	-	-	-	-	-	-

Connector connected to encoder housing

Accessories

IP40		KD-7-40	-	KM-6-40	-
IP40		KDA-7-40	-	-	-
IP65		-	-	-	KVA-4-65
IP67		KD-7-67	-	KD-12-67	-
IP67		KDA-7-67	-	KDA-12-67	-

Pin assignment connector SK6 (M8x1) 6-pin and SB/SC (M12x1), 5-, 6-, 8-, 12-pin:

	M8x1			M12x1							
Type	M8x1			M12x1							
Description	SK6 axial, 6-pin	SB4 axial, SC4 radial, 4-pin	SB5 axial, SC5 radial, 5-pin	SB8 axial, SC8 radial, 8-pin				SB12 axial, SC12 radial, 12-pin			
Circuit	N05 N24 N30	F/H05 F/H24 H30	F/H05 F/H24 H30	F/H05 F/H24 H30	P/R05 P/R24 R30 245 645	SIN WDG80H WDG100H	SIN WDG58 WDG63 WDG67 WDG70 WDG115	G05 G24	F/H05 F/H24 H30	I05 I24 524	P/R05 P/R24 245 645 R30
Minus U-	3	3	3	1	1	1	1	3	3	3	3
Plus U+	2	1	1	2	2	2	2	1	1	1	1
A	4	2	4	3	3	3	3	4	4	4	4
B	5	4	2	4	4	5	5	6	6	6	6
N	1	-	5	5	5	7	-	8	8	8	8
Light reserve warning	-	-	-	-	-	-	-	5	-	5	-
A inv.	-	-	-	-	6	4	4	-	-	9	9
B inv.	-	-	-	-	7	6	6	-	-	7	7
N inv.	-	-	-	-	8	8	-	-	-	10	10
n. c.	6	-	-	6, 7, 8	-	-	7, 8	2, 7, 9, 10, 11, 12	2, 11, 12	2, 11, 12	2, 5, 11, 12
Shield	-	-	-	-	-	-	-	-	-	-	-

Connector connected to encoder housing

Accessories

IP67		5 m	SAK-6-67-05	KI-4-67-05-S	KI-5-67-05-S	KI-8-67-05-S	KI-8-67-SIN-05	KI-12-67-05-S
IP67		5 m	-	KIA-4-67-05-S	KIA-5-67-05-S	KIA-8-67-05-S	KIA-8-67-SIN-05	KIA-12-67-05-S
IP67		10 m	-	KI-4-67-10-S	KI-5-67-10-S	KI-8-67-10-S	KI-8-67-SIN-10	KI-12-67-10-S
IP67		10 m	-	KIA-4-67-10-S	KIA-5-67-10-S	KIA-8-67-10-S	KIA-8-67-SIN-10	KIA-12-67-10-S

Pin assignment SUBD-connector, 15-polig:

	SUBD-connector			
Type	SUBD-connector			
Description	SD15 radial 15-pin			
Circuit	H05 H24 H30 F05 F24	245 R05 R24 R30 P05 P24 645	SIN	SIF
Minus U-	4	4	4	4
Plus U+	3	3	3	3
A	1	1	1	1
B	5	5	5	5
N	7	7	7	7
Light reserve warning	-	-	-	14
A inv.	-	2	2	2
B inv.	-	6	6	6
N inv.	-	8	8	8
n. c.	2, 6, 8, 9, 10, 11, 13, 14, 15	9, 10, 11, 13, 14, 15	9, 10, 11, 13, 14, 15	9, 10, 11, 13, 15
Shield	12	12	12	12

Connector connected to encoder housing

Output circuits / Electrical Data Sin/Cos

Key	SIN / SIF (Sinus/Cosinus)
Power supply	4,75 VDC up to 5,5 VDC
Current consumption	max. 100 mA without load
Channels / Output	Sinus, Cosinus, (N)
Load on the output	min. 120 Ohm terminating resistor between + and - output
Signal level	1 V _{SS} +/- 25%
Limit frequency (-3dB)	100 kHz
Circuit protection	no
Light reserve warning	Circuit SIN: no Circuit SIF: yes (except 80H, 100H)
Cable length	max. 150 m at <260pF/m

Key	G24 (HTL)	H24 (HTL)	F24 (HTL)	N24 (HTL)	I24 (HTL)	R24 (HTL)	P24 (HTL)	M24 (HTL)	
Output circuit									
Power supply	10 VDC up to 30 VDC								
Current consumption	max. 70 mA		max. 100 mA		max. 40 mA		max. 70 mA		
Channels	A, B, N				A, B, N, \bar{A} , \bar{B} , \bar{N}				
Output	push-pull								
Load	max. 40 mA / channel			max. 30 mA / channel		max. 40 mA / channel		max. 30 mA / channel	
Signal level	at 20 mA $H > U_B - 2.5$ VDC $L < 2.5$ VDC								
Pulse frequency	max. 200 kHz		max. 600 kHz		max. 20 kHz		max. 200 kHz		
Circuit protection	yes								
Light reserve warning	yes	no			yes	no			

Key	G05 (TTL)	H05 (TTL)	F05 (TTL)	N05 (TTL)	I05 (RS422 TTL)	R05 (RS422 TTL)	P05 (RS422 TTL)	M05 (RS422 TTL)	
Output circuit									
Power supply	4,75 VDC up to 5,5 VDC								
Current consumption	max. 70 mA		max. 100 mA		max. 40 mA		max. 70 mA		
Channels	A, B, N				A, B, N, \bar{A} , \bar{B} , \bar{N}				
Output	Gegentakt								
Load	max. 40 mA / channel			max. 30 mA / channel		max. 40 mA / channel		max. 30 mA / channel	
Signal level	at 20 mA $H > 2.5$ VDC $L < 0.5$ VDC								
Pulse frequency	max. 200 kHz		max. 2 MHz		max. 20 kHz		max. 200 kHz		
Circuit protection	no								
Light reserve warning	yes	no			yes	no			

Key	245 (RS422 TTL)	524 (RS422 TTL)	645 (RS422 TTL)	N30 (HTL)	H30 (HTL)	R30 (HTL)	M30 (HTL)	
Output circuit								
Power supply	10 VDC up to 30 VDC			5 VDC up to 30 VDC				
Current consumption	max. 70 mA		max. 100 mA		max. 40 mA		max. 70 mA	
Channels	A, B, N, \bar{A} , \bar{B} , \bar{N}			A, B, N		A, B, N, \bar{A} , \bar{B} , \bar{N}		
Output	Gegentakt							
Load	max. 40 mA / channel			max. 30 mA / channel		max. 40 mA / channel		max. 30 mA / channel
Signal level	at 20 mA $H > 2.5$ VDC $L < 1.2$ VDC			at 20 mA $H > U_B - 10\%$ U_B $L < 2.5$ VDC				
Pulse frequency	max. 200 kHz		max. 2 MHz		max. 200 kHz			
Circuit protection	only inverse-polarity protection			no		only inverse-polarity protection		no
Light reserve warning	no	yes	no	no				