Wachendorff Automation GmbH & Co. KG
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General technical data – Incremental encoders

Safety instructions:
a. If a riskless operation can no longer be assured, the unit has to be shut down immediately and be secured against unintended start up.
b. In any case of possible hazard of people or possible damage of equipment if the encoder fail, precautions have to be taken to prevent it before start.

Optical principle
All the WDG incremental encoders from Wachendorff (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 90º, 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 encoders are finely-tuned measuring systems, made up of a combination of precision mechanics, a compact optical segment and high-performance electronics.

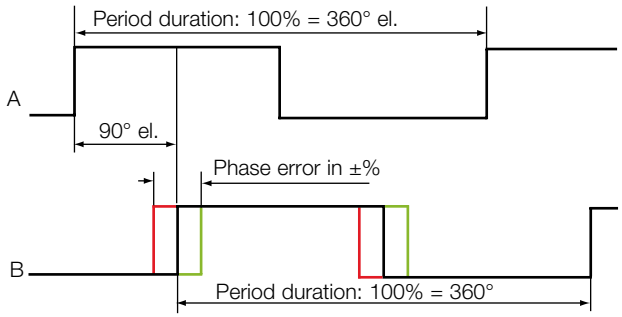
Optics

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

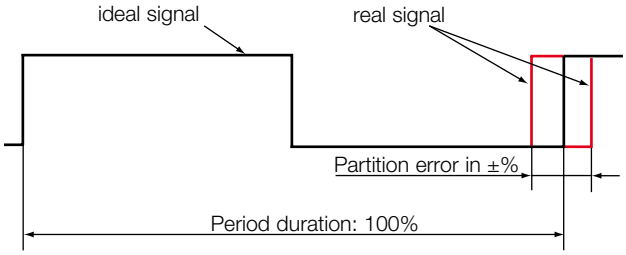
Accuracy incremental encoders
Shaft encoders have three defined types of accuracy. In each case the accuracy is given as a % of the pulse length, which consists of a pulse and a pause.
The partition error is defined as the deviation of any pulse edge from its exact geometric position and as standard 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 measured at ambient temperature.

Phase offset:



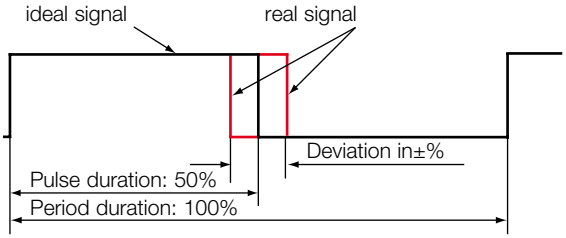
El. phase offset: 90° ± max. phase error 7,5% of a pulse length

Partition error:



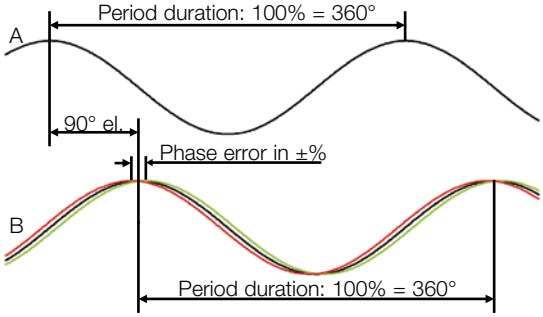
Partition: max. 12%

Pulse-/Pause-ratio



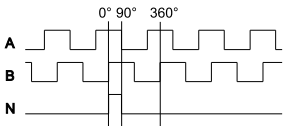
Pulse-/Pause-ratio: ≤5000 PPR: 50 % max. ±7 %,
>5000 PPR: 50 % max. ±10 %
(WDG24C: 1 PPR up to 128 PPR: 50 % max. ±10 %
256 PPR, 512 PPR, 1024 PPR: 50 % max. ±23 %)

Accuracy sinus encoders
Phase offset:

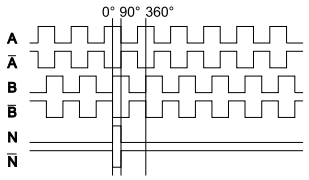


El. phase offset: 90° ± max. phase error 7,5% of a pulse length

Pulse diagram



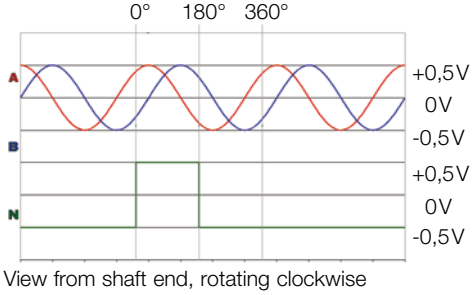
G24, F24, H24, G05, F05, H05, H30, N05, N30



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

View from shaft end, rotating clockwise

SINUS
-Pulse figure (differential input)



View from shaft end, rotating clockwise

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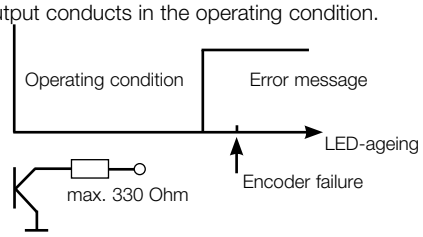
Light reserve warning

For the purpose of preventive maintenance, Wachendorff optical encoders that have the output circuits G24, G05, I24, I05, 524 and SIF (SIF only for WDG80H and WDG100G/H/I) 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.

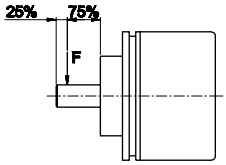


Output switching:
With light reserve warning: G05, G24, I05, I24, 524 (not for WDG40xx), SIF (SIF with light reserve warning only WDG80H and WDG100H/G)

Without light reserve warning:
F05, F24, H05, H24, N05, N30, M05, 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.



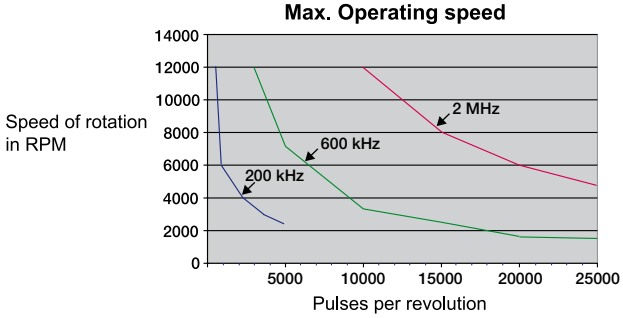
The bearings are treated with a special grease able to withstand extreme temperatures, high speeds and loads, as well as constant operation in reverse. The grease remains stable over a long period of time. The indicated radial-bearing load relates to the point F of the applied force. The useful life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

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

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:

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



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:

$$f \text{ in Hz}_{(max)} = \frac{\text{(max shaft speed in RPM) x (pulses per revolution PPR)}}{60}$$

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 f_{aus}	I24/R24 f_{aus}
10 m	10-30 V	200 kHz	200 kHz
50 m	12 V 24 V 30 V	200 kHz 200 kHz 150 kHz	200 kHz 100 kHz 50 kHz
100 m	12 V 24 V 30 V	200 kHz 200 kHz 70 kHz	200 kHz 50 kHz

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

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

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

Output circuit	Power supply	245/524 f_{aus}	645 f_{aus}
100 m	10 - 30 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	R30/H30 f_{aus}
10 m	5-30 V	200 kHz
50 m	5 V 12 V 24 V 30 V	200 kHz 155 kHz 75 kHz 58 kHz
100 m	5 V 12 V 24 V 30 V	200 kHz 70 kHz 30 kHz 24 kHz

Connection safety:

All encoders with output circuits G24, H24, I24, R24, F24, and P24 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.

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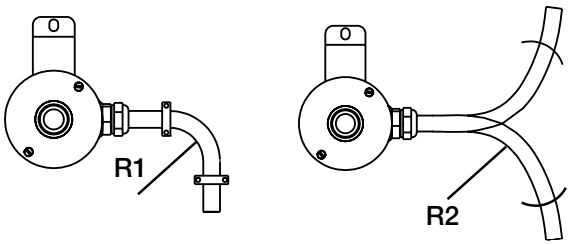
	Cable for encoders without low-temperature			Cable T3	Cable for encoders with low-temperature ACA -40 °C (-40 °F)	
Encoder types	all encoder types except 24, 40, 58T, 58S, 58V	58S, 58V	24C, 40, 58T	58M	24C, 40	50B, 53, 58, 70B, 80H, 100G/H/I, 115T, 115M
Core	stranded copper wire					
Cross-section for singnal lines power lines	0.14 mm² 0.34 mm²	0.14 mm² 0.34 mm²	0.14 mm² 0.14 mm²	0.14 mm² 0.14 mm²	0.14 mm² 0.14 mm²	0.14 mm² 0.34 mm²
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 mm² max.: for 0.34 mm² 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

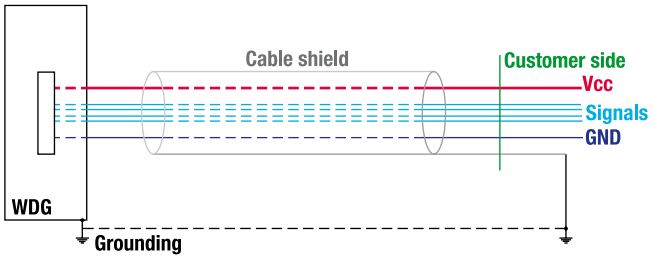
Cable Ø	R1	R2	Temperature
≤ 7 mm	46,5 mm	139,5 mm	T > -40 °C (-40 °F)
> 7 mm	62,3 mm	186,9 mm	T > -40 °C (-40 °F)

Encoders with cable T3

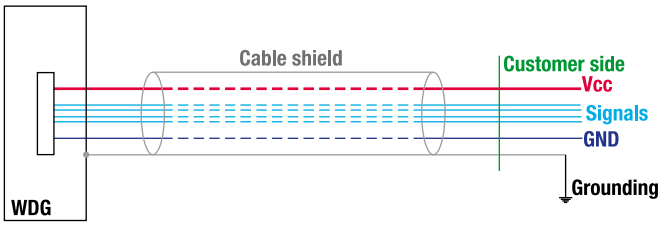
Cable Ø	R1	R2
6 mm	30 mm	90 mm
	T > -40 °C (-40 °F)	T > -10 °C (-14 °F)

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 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/s² (10-2000 Hz)
Shock (IEC 68-2-27):	1000m/s² (6 ms)
Design according to:	DIN VDE 0160

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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 Type	F/H05 F/H24 H30	245 R05 R24	R30 58T	G05 G24	F/H05 F/H24 H30	I05 I24 524 not 58S, 58V	I05 I24 524 ACA: 58, 63, 67, 70, 115	P/R05 P/R24 245 645 R30 not 58S, 58V	P/R05 P/R24 245 645 ACA: 58, 63, 67, 70, 115	R24 ACA: 40A/S/E	SIN 58 63 67 70 115	SIN 80H 100G/H/I	SIF 80H 100G/H/I
Minus U-	WH	WH	WH	WH	WH	WH	WH	WH	WH	WH	WH	WH	WH
Plus U+	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN
A	GN	GN	GN	GN	GN	GN	GN	GN	GN	GN	GN	GN	GN
B	YE	YE	YE	YE	YE	YE	YE	YE	YE	YE	GY	GY	GY
N	GY	GY	GY	GY	GY	GY	GY	GY	GY	GY	-	BK	BK
Light reserve warning	-	-	-	PK	-	PK	PK	-	-	-	-	-	RD
A inv.	-	RD	RD	-	-	RD	RD	RD	RD	RD	YE	YE	YE
B inv.	-	BK	PK	-	-	BK	BU	BK	BU	BK	PK	PK	PK
N inv.	-	VT	BU	-	-	VT	VT	VT	VT	VT	-	VT	VT
Shield	flex												
	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 Type	N05 N30	M05 M30	M05 M30 ACA
Minus U-	WH	WH	WH
Plus U+	BN	BN	BN
A	GN	GN	GN
B	YE	YE	YE
N	GY	GY	GY
Light reserve warning	-	-	-
A inv.	-	RD	RD
B inv.	-	PK	BK
N inv.	-	BU	VT
Schirm	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

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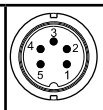
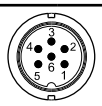
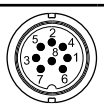
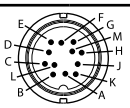
Pin assignment connector SI/SH (M16x0,75), 5-, 6-, 8-, 12-pin:

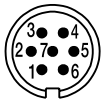
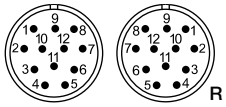





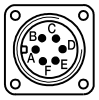
Type	**M16x0,75**												
Bezeichnung	**SI5 axial, SH5 radial, 5-pin**	**SI6 axial, SH6 radial, 6-pin**		**SI8 axial, SH8 radial, 8-pin**			**SI12 axial, SH12 radial, 12-pin**						
Circuit	**F/H05 F/H24 H30**	**G05 G24**	**F/H05 F/H24 H30**	**F/H05 F/H24 H30**	**P/R05 P/R24 R30, 245, 645, SIN** SIN only 80H 100G/H/I	**SIN** 58 63 67 70 115	**G05 G24**	**F/H05 F/H24 H30**	**I05 I24 524**	**P/R05 P/R24 245 645 R30**	**SIN** 58 63 67 70 115	**SIN** 80H 100G/H/I	**SIF** 80H 100G/H/I
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** 58 63 67 70 115	**SIN** 80H 100G/H/I	**SIF** 80H 100G/H/I	**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	6, 7	1, 2, 4, 6, 7, 9	1, 2, 4, 6, 7, 9, 11	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	-	-

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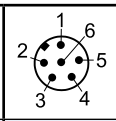
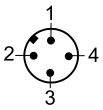
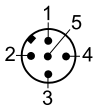
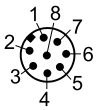
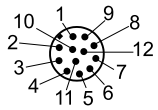
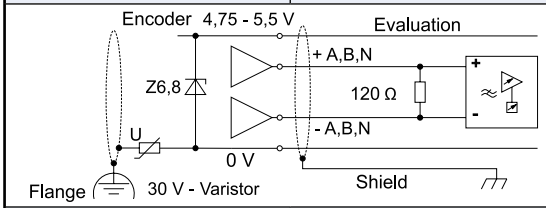
Pin assignment connector SK6 (M8x1) 6-pin and SB/SC (M12x1), 5-, 6-, 8-, 12-pin:

											
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 N30**	**F/H05 F/H24 H30**	**F/H05 F/H24 H30**	**F/H05 F/H24 H30**	**P/R05 P/R24 R30 245 645**	**SIN** 80H 100G/H/I	**SIN** 58 63 67 70 115	**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

Output circuits / Electrical Data Sin/Cos

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

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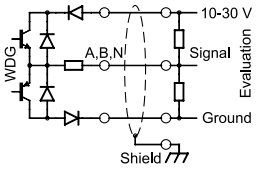
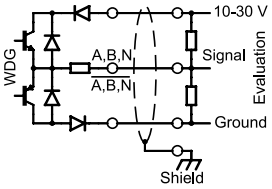
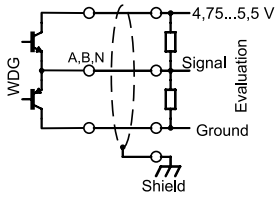
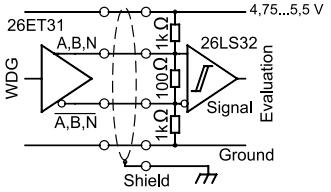
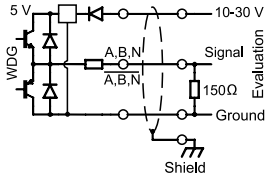
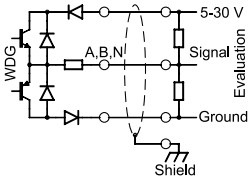
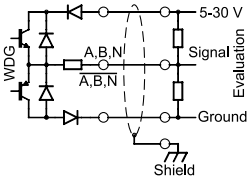
Key	G24 (HTL)	H24 (HTL)	F24 (HTL)	I24 (HTL)	R24 (HTL)	P24 (HTL)
Output circuit						
Power supply	10 VDC up to 30 VDC					
Current consumption	typ. 70 mA		typ. 100 mA	typ. 70 mA		typ. 100 mA
Channels	A, B, N			A, B, N, $\overline{A}$, $\overline{B}$, $\overline{N}$		
Output	push-pull					
Load	max. 40 mA / channel			max. 40 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. 200 kHz		max. 600 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	typ. 70 mA		typ. 100 mA	typ. 40 mA	typ. 70 mA		typ. 100 mA	typ. 40 mA
Channels	A, B, N				A, B, N, $\overline{A}$, $\overline{B}$, $\overline{N}$			
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 > 2.5 VDC L < 0.5 VDC							
Pulse frequency	max. 200 kHz		max. 2 MHz	max. 20 kHz	max. 200 kHz		max. 2 MHz	max. 20 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	typ. 70 mA		typ. 100 mA	typ. 40 mA	typ. 70 mA		typ. 40 mA
Channels	A, B, N, $\overline{A}$, $\overline{B}$, $\overline{N}$			A, B, N		A, B, N, $\overline{A}$, $\overline{B}$, $\overline{N}$	
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 > 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			