WACHENDORFF
The Encoder Experts

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General technical data – Incremental encoders

Safety instructions

1a If a riskless operation can no longer be assured, the unit has to be shut down immediately and be secured against unintended start up.
1b 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 output circuits Nxx/Mxx) 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.

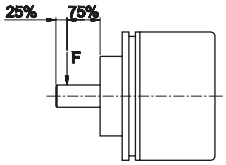
Our encoders are finely-tuned measuring systems, made up of a combination of precision mechanics, a compact optical segment and high-performance electronics.

Magnetic principle

The WDG incremental encoders with output circuits Nxx/Mxx work on a non-contact magnetic scanning principle. A diametral agnetised 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 2 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.

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.



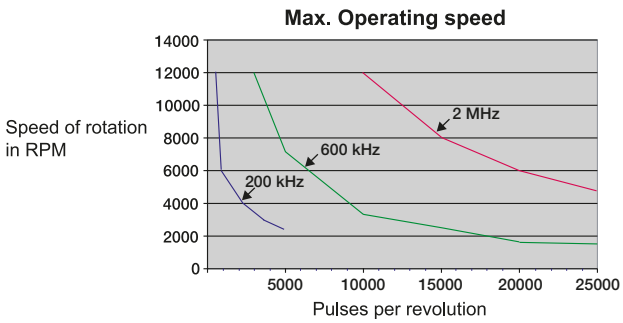
The bearings are treated with a special grease able to withstand extreme temperatures, high speeds and loads, as well as constant operation in reverse. The grease remains stable over a long period of time. The indicated radial-bearing load relates to the point F of the applied force. The useful life 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:

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



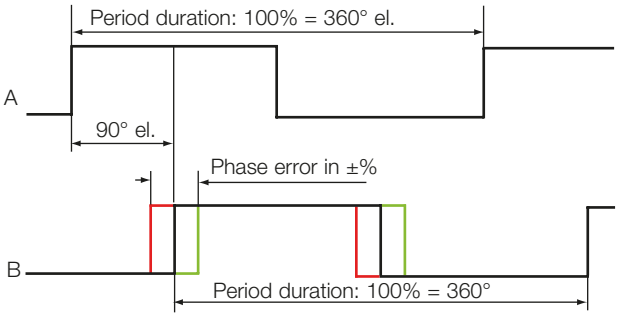
Accuracy incremental encoders

Shaft encoders have two defined types of accuracy. In each case the accuracy is given as a % of the period duration, which consists of a pulse and a pause. The pulse/pause ratio describes the ratio of the pulse length from the period duration. The phase displacement describes the accuracy of two successive edges.

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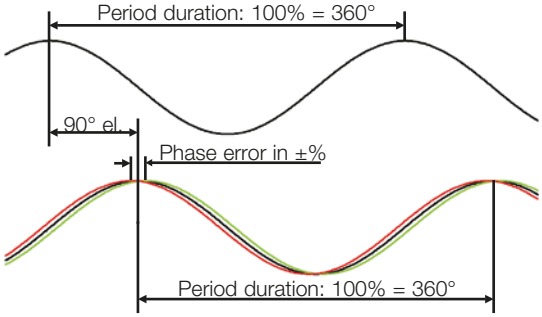
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Phase offset:



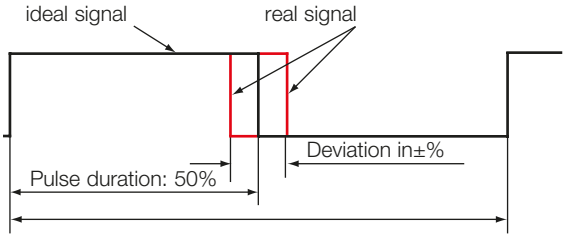
El. phase offset:
90° ± max. phase error 7,5% of a period duration
at **WDG** Nxx/Mxx: 90° ± max. phase error 25% of a period duration

Accuracy sinus encoders
Phase offset:



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

Pulse-/Pause-ratio:



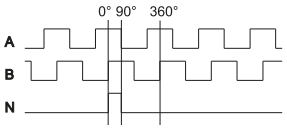
Pulse-/Pause-ratio:

WDG/WDGI Gxx/Hxx/Ixx/Rxx/245/524: 50 % max. ±7%,
WDG/WDGI Fxx/Pxx/645: 50% max. ±10%

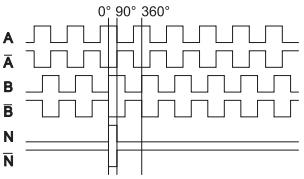
WDG Nxx/Mxx:	1 ppr up to 128 ppr: 50 % max. ±7%
	256 ppr: 50% max. ±9%
	512 prr: 50% max. ±13%
	1024 ppr: 50% max. ±18%
WDGI N35/M35:	50% max. ±7%

Pulse diagram*

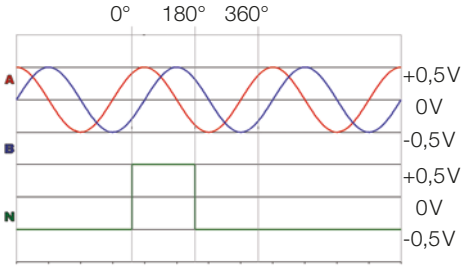
Gxx, Fxx, Hxx, Nxx



Ixx, Rxx, Pxx, Mxx, 245, 524, 645

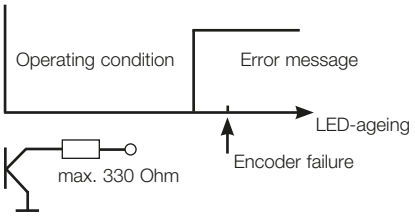


SINUS-Pulse figure (differential input)



*View of shaft, clockwise rotation in each case

Light reserve warning
For the purpose of preventive maintenance, Wachendorff optical encoders that have the output circuits G24, G05, I24, I05, 524 and SIF 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.



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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 meter	10-30 V	200 kHz	200 kHz
50 meter	12 V 24 V 30 V	200 kHz 200 kHz 150 kHz	200 kHz 100 kHz 50 kHz
100 meter	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 meter	12 V 24 V 30 V	560 kHz 350 kHz 280 kHz	450 kHz 350 kHz 280 kHz
50 Meter	12 V 24 V 30 V	250 kHz 150 kHz 100 kHz	200 kHz 100 kHz 50 kHz
100 meter	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 meter	5 V	200 kHz	200 kHz

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

Output circuit	Power supply	245/524 f_{aus}	645 f_{aus}
100 meter	10-30 V	200 kHz	2 MHz

Output circuit	Power supply	M30/N30 f_{aus}
25 meter	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}	N35 (WDG) f_{aus}	M35 (WDG) f_{aus}	N35 (WDGI) f_{aus}	M35 (WDGI) f_{aus}
10 meter	5 V 12 V 24 V 30 V	200 kHz 200 kHz 200 kHz 200 kHz	200 kHz 200 kHz 200 kHz 200 kHz	200 kHz 200 kHz 200 kHz 200 kHz	1 MHz 1 MHz 460 kHz 280 kHz	1 MHz 1 MHz 370 kHz 210 kHz
50 meter	5 V 12 V 24 V 30 V	200 kHz 155 kHz 75 kHz 58 kHz	200 kHz 200 kHz 200 kHz 150 kHz	200 kHz 200 kHz 100 kHz 50 kHz	1 MHz 1 MHz 200 kHz 130 kHz	1 MHz 1 MHz 120 kHz 70 kHz
100 meter	5 V 12 V 24 V 30 V	200 kHz 70 kHz 30 kHz 24 kHz	200 kHz 200 kHz 200 kHz 70 kHz	200 kHz 200 kHz 50 kHz	1 MHz 800 kHz 140 kHz 70 kHz	1 MHz 600 kHz 70 kHz 35 kHz

Cable length:

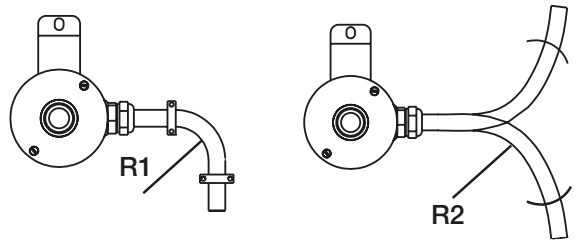
Using Wachendorff encoder cable a cable run of up to 100 m is possible (150 m for SINUS encoders). However the actual achievable cable length depends on the possible effects of noise interference and should therefore be checked for each individual case. Please refer to the tables regarding the max. output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

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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	50B, 53V, 58A/B/C/D/E/H/K/N 63B/Q, 67Q, 70B, 80H, 100G/H/I, 115M/T	58S, 58V	24C, 30A, 58T	36A/C/E/K/S 40A/E/K/S	58M	24C, 30A 36A/C/E/K/S 40A/E/K/S	50B, 53V, 58A/B/C/D/E/H/K/N 63B/Q, 67Q, 70B, 80H 100G/H/I, 115M/T
Core	stranded copper wire						
Cross-section for singnal lines power lines	0.14 mm² [AWG 26] 0.34 mm² [AWG 22]	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 diameter at circuits: inverted not inverted	7.7 mm [0.3"] 6.3 mm [0.25"]	8.3 mm 8.3 mm [0.327"]	6.0 mm 6.0 mm [0.236"]	7.0 mm [0.276"] 6.0 mm [0.236"]	6.0 mm 6.0 mm [0.236"]	6.2 mm 6.2 mm [0.244"]	8.3 mm 8.3 mm [0.327"]
Shield	Tinned braided copper. Stranded filter wire for simple connection						
Outer sheath	PVC, grey	TPE, grey	PVC, grey		PVC, black	PUR, black	TPE, grey
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 ca. 155 nF/km				120 nF/km ca. 120 nF/km	140 nF/km ca. 155 nF/km	

Permissible bending radii Cable:



Encoders without low-temperature

Kabel Ø	R1	R2	Temperatur
≤ 7 mm [0.276"]	31.5 mm [1.24"]	94.5 mm [3.72"]	T > -20 °C (-4 °F)
> 7 mm [0.276"]	41.5 mm [1.634"]	124.5 mm[4.9"]	T > -20 °C (-4 °F)

Encoders with low-temperature

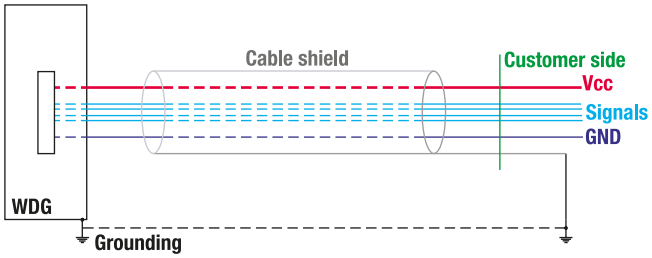
Kabel Ø	R1	R2	Temperatur
≤ 7 mm [0.276"]	46.5 mm [1.83"]	139.5 mm [5.49"]	T > -40 °C (-40 °F)
> 7 mm [0.276"]	62.3 mm [2.45"]	186.9 mm [7.36"]	T > -40 °C (-40 °F)

Encoders with cable T3

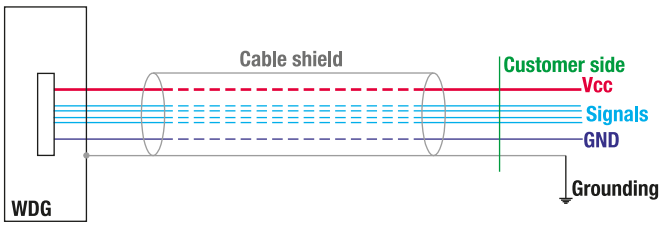
Kabel Ø	R1	R2
6 mm [0.236"]	30 mm [1.181"] T > -40 °C (-40 °F)	90 mm [3.543"] T > -10 °C (-14 °F)

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.

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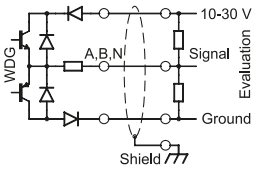
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Key	Output circuit	Power supply	Current consumption	Channels	Output	Load	Signal level (at 20 mA)	Pulse frequency	Light reserve warning
G24	HTL	10 VDC up to 30 VDC	typ. 70 mA	A, B, N	push-pull	max. 40 mA/channel	H > UB - 2,5 VDC L < 2,5 VDC	max. 200 kHZ	yes
H24									no
F24			typ. 100 mA					max. 600 kHZ	
I24			typ. 70 mA	A, B, N $\overline{A}$, $\overline{B}$, $\overline{N}$				max. 200 kHZ	yes
R24									no
P24			typ. 100 mA					max. 600 kHZ	
G05	TTL	4,75 VDC up to 5,5 VDC	typ. 70 mA	A, B, N		max. 40 mA/channel	H > 2,5 VDC L < 0,5 VDC	max. 200 kHZ	yes
H05									no
F05			typ. 100 mA					max. 2 MHZ	
N05			typ. 40 mA	A, B, N $\overline{A}$, $\overline{B}$, $\overline{N}$		max. 30 mA/channel		max. 20 kHZ	
M05	RS422 (TTL)		typ. 70 mA			max. 40 mA/channel		max. 200 kHZ	yes
I05									no
R05			typ. 100 mA					max. 2 MHZ	
P05									
524		10 VDC up to 30 VDC	typ. 70 mA				H > 2,5 VDC L < 1,2 VDC	max. 200 kHZ	yes
245									no
645			typ. 100 mA					max. 2 MHZ	
N30	HTL (TTL at 5 VDC)	5 VDC up to 30 VDC	typ. 40 mA	A, B, N		max. 30 mA/channel	H > UB - 10% UB L < 2,5 VDC	max. 200 kHZ	no
M30				A, B, N $\overline{A}$, $\overline{B}$, $\overline{N}$					
R30			typ. 70 mA			max. 40 mA/channel			
H30				A, B, N					
N35 (WDG)			typ. 40 mA						
M35 (WDG)				A, B, N $\overline{A}$, $\overline{B}$, $\overline{N}$					
M35 (WDGI)		4,75 VDC up to 30 VDC						max. 600 kHZ HTL max. 1 MHz TTL	
N35 (WDGI)				A, B, N					

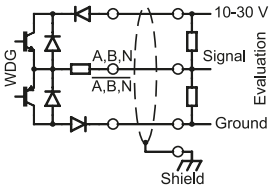
Key	Chanells / Output	Power supply	Current consumption	Cable length	Signal level	Limit frequency (-3dB)	Load on the output	Light reserve warning
SIN	Sinus, Cosinus (N)	4,75 VDC up to 5,5 VDC	typ. 100 mA without load	max. 150 m bei <260 pF/m	1 Vpp +/- 25%	100 kHz	min. 120 Ohm terminating resistor between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

Output circuits

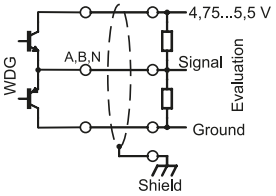
G24, H24, F24



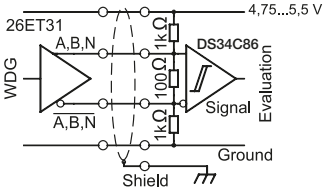
I24, R24, P24



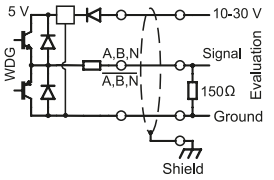
G05, H05, F05, N05



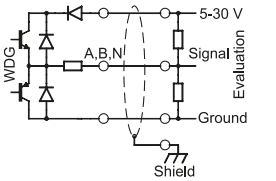
I05, R05, P05, M05



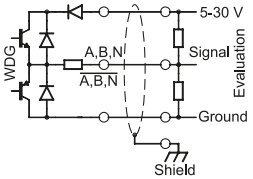
245, 524, 645



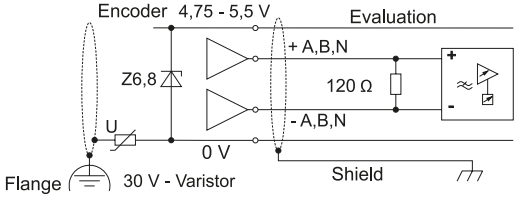
N30, H30, N35



M30, R30, M35



SIN, SIF



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Key	Circuit protection	Inverse-polarity protection	Short circuit protection
G24	yes	yes	yes
H24	yes	yes	yes
F24	yes	yes	yes
I24	yes	yes	yes
R24	yes	yes	yes
P24	yes	yes	yes
G05	no	no	yes
H05	no	no	yes
F05	no	no	yes
N05	no	no	no
I05	no	no	yes
R05	no	no	yes
P05	no	no	yes
M05	no	no	no

Key	Circuit protection	Inverse-polarity protection	Short circuit protection
245	no	no	yes*
524	no	no	yes*
645	no	no	yes*
N30	no	no	no
N35 (WDG)	no	no	yes
N35 (WDGI)	yes	yes	yes
H30	no	yes	yes
R30	no	yes	yes
M35 (WDG)	no	no	yes
M35 (WDGI)	yes	yes	yes
M30	no	no	no
SIN	no	no	yes
SIF	no	no	yes

Inverse-polarity protection:
Reversing the connection cables of the power supply when the outputs are connected correctly will not result in damage. However, the function is not guaranteed.

Short circuit protection:
Requirements:
- Supply lines not reversed!
- Only one output is short-circuit-proof against GND, +UB (max. allowable supply voltage) or another output.
  *for 245/524/645 only between two outputs or GND.

Circuit protection:
Reversing the polarity of the power supply while simultaneously short-circuiting the outputs to each other or to GND or +UB will not result in damage. Applying GND and +UB to two outputs is not permitted and can lead to failure.