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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 of possible hazard of people or possible damage of equipment if the encoder fails, 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.

**Optics**

| | |
|---|---|
| Light source: | IR - LED |
| Service life: | typ. 100.000 hours., WDG58T: 80.000 hours |
| Std. Scanning: | differential |

**Magnetic principle**

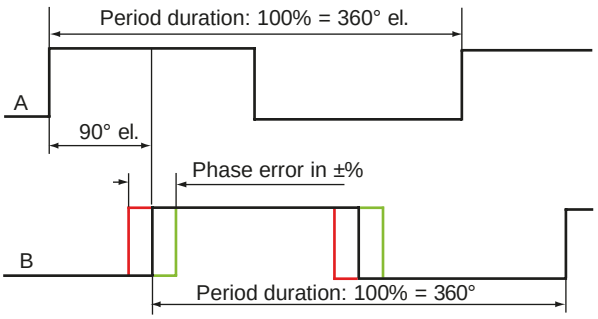
The WDG incremental encoders with output circuits Nxx/Mxx work on a non-contact magnetic scanning principle. A diametral magnetized magnet is mounted in the stainless-steel shaft with its backlash-free bearings. If the shaft is rotated, the magnet and the magnetic field rotate with it. This change in 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**

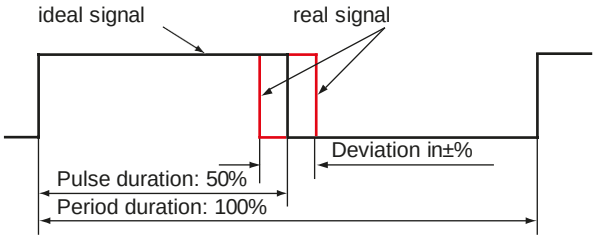
Shaft encoders have two defined types of accuracy. In each case the accuracy is given as a % of the period duration, which consists of a pulse and a pause.
The pulse/pause ratio describes the ratio of the pulse length from the period duration. The phase displacement describes the accuracy of two successive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

**Phase offset:**




El. Phase offset:
90° ± max. phase error 7.5 % of a period duration
Nxx/Mxx: 90° ± max. phase error 25 % of a period duration

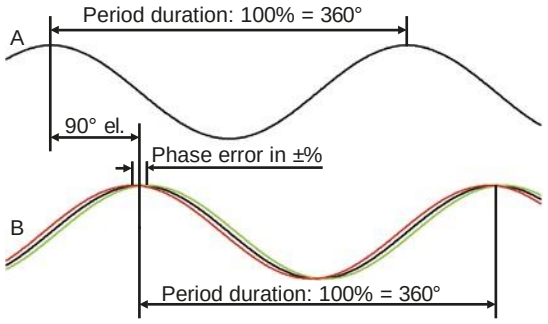
**Pulse-/Pause-ratio:**




Pulse-/ Pause-ratio:
≤5000 I/U: 50 % max. ±7 %,
Output circuits F24, P24, F05, P05, 645: 50 % max. ±10 %
Nxx/Mxx: 1 I/U bis 128 I/U: 50 % max. ±7 %,
256 I/U: 50 % max. ±9 %.
512 I/U: 50 % max. ±13 %.
1024 I/U: 50 % max. ±18 %.

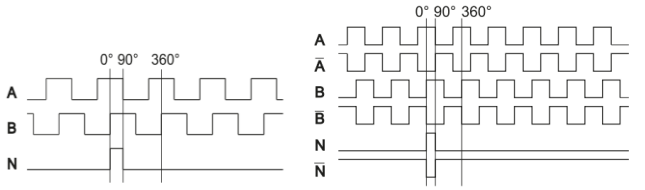
**Accuracy sinus encoders**

Phase offset:




El. Phase offset: 90° ± max. phase error 7.5 % of a period duration

**Pulse diagram**

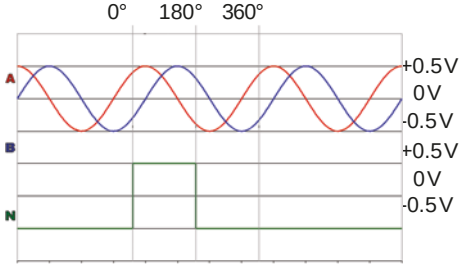



G24, F24, H24, G05, F05, H05, H30, N05, N30, N35

I24, R24, P24, I05, R05, M05, M30, M35, 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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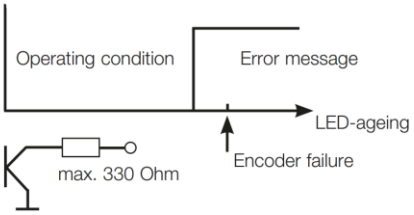
**Light reserve warning**
or the purpose of preventive maintenance, Wachendorff optical encoders that have the output circuits G24, G05, I24, I05, 524 and SIF (SIF only for WDG80H and WDG100G/H/I) are equipped with an early warning output. When the LED intensity drops to a level approximately 10 % of its original value, this output provides a warning of the impending failure of the encoder signals.

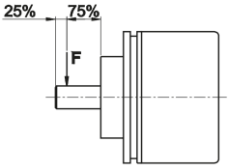
Nevertheless, the optical encoder will continue to operate for more than 1000 hours and can thus be replaced during normal servicing. The early warning output conducts in the operating condition.




Output switching:
G05, G24, I05, I24, 524, SIF

Without light reserve warning:
F05, F24, H05, H24, N05, N30, N35, M05, M30, M35, 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.

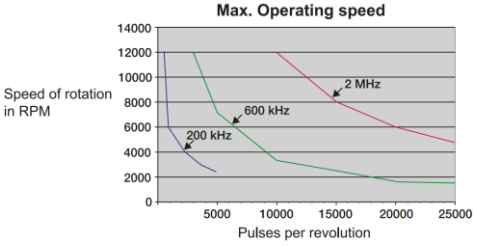



The bearings are treated with a special grease able to withstand extreme temperatures, high speeds and loads, as well as constant operation in reverse. The grease remains stable over a long period of time. The indicated radial-bearing load relates to the point F of the applied force. The useful life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

$$f \text{ in } Hz_{(max)} = \frac{\text{(max. shaft speed in RPM) x (pulses/ rev. PPR)}}{60}$$

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 $f_{out}$ | I24/ R24 $f_{out}$ |
|---|---|---|---|
| 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 $f_{out}$ | P24 $f_{out}$ |
|---|---|---|---|
| 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 $f_{out}$ | I05/R05 $f_{out}$ |
|---|---|---|---|
| 100 m | 5 V | 200 kHz | 200 kHz |

| Output circuit | Power supply | F05 $f_{out}$ | P05 $f_{out}$ |
|---|---|---|---|
| 100 m | 5 V | 2 MHz | 2 MHz |

| Output circuit | Power supply | 245/524 $f_{out}$ | 645 $f_{out}$ |
|---|---|---|---|
| 100 m | 10 - 30 V | 200 kHz | 2 MHz |

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

| Output circuit | Power supply | M05/N05 $f_{out}$ |
|---|---|---|
| 10 m | 4.75-5.5 V | 20 kHz |

| Output circuit | Power supply | R30/ H30 $f_{out}$ | N35 $f_{out}$ | M35 $f_{out}$ |
|---|---|---|---|---|
| 10 m | 5-30 V | 200 kHz | 200 kHz | 200 kHz |
| 50 m | 5 V | 200 kHz | 200 kHz | 200 kHz |
| | 12 V | 155 kHz | 200 kHz | 200 kHz |
| | 24 V | 75 kHz | 200 kHz | 100 kHz |
| | 30 V | 58 kHz | 150 kHz | 50 kHz |
| 100 m | 5 V | 200 kHz | 200 kHz | 200 kHz |
| | 12 V | 70 kHz | 200 kHz | 200 kHz |
| | 24 V | 30 kHz | 200 kHz | 50 kHz |
| | 30 V | 24 kHz | 70 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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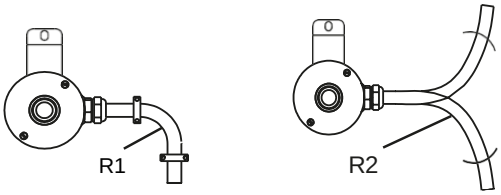
| | Cable for encoders without low temperature | | | cable T3 | Cable for encoders with low temperature ACA -40 °C (-40 °F) | |
|---|---|---|---|---|---|---|
| Encoder types | All encoder types except 24, 30, 36, 40, 58T, 58S, 58V | 58S, 58V | 24C, 30, 36, 40, 58T | 58M | 24C, 30A, 36, 40 | 50B, 53, 58, 70B, 80H, 100H/G/I, 115T, 115M |
| Core | Stranded copper wire | | | | | |
| Cross-section for Signal 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: 36, 40 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 steath | 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 with 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**

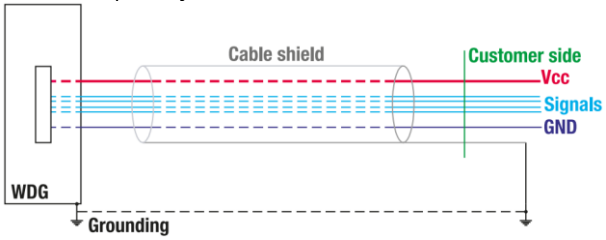
| Cable Ø | R1 | R2 | Temperature |
|---|---|---|---|
| ≤ 7 mm | 46.5 mm | 139.5 mm | T > -40°C (-40°F) |
| > 7 mm | 62.3 mm | 186.9 mm | T > -40°C (-40°F) |

**Encoders with T3**

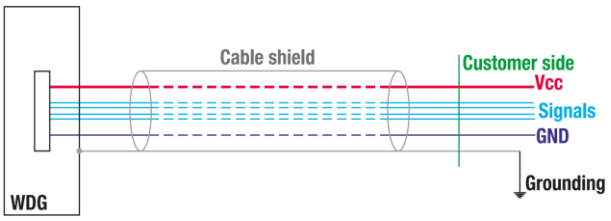
| Cable Ø | R1 | R2 |
|---|---|---|
| 6mm | 30 mm T >-40°C (-40°F) | 90 mm T > -10°C (-14°F) |

**Cable length:**
sing Wachendorff encoder cable a cable run of up to 100 m is possible (150 m for SINUS encoders). How ever 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.

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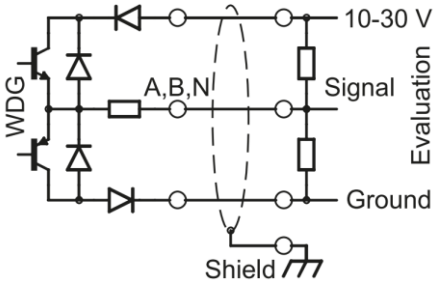
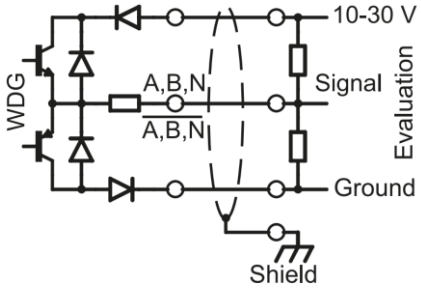
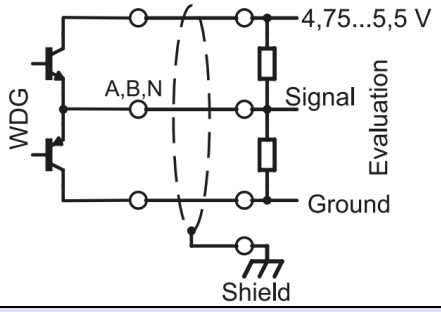
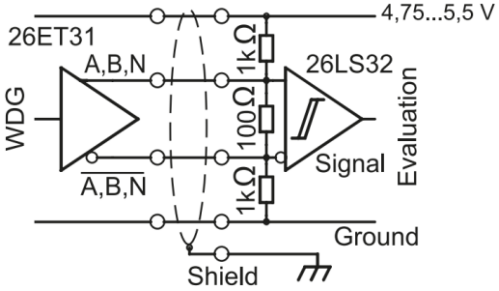
| Key | G24 (HTL) | H24 (HTL) | F24 (HTL) | I24 (HTL) | R24 (HTL) | P24 (HTL) |
|---|---|---|---|---|---|---|
| Output circuit |  | | |  | | |
| Power supply | 10 VDC up to 30 VDC | | | | | |
| Current consumption | Typ. 70 mA | | Typ. 100mA | Typ.70 mA | | Max. 100 mA |
| Channels | A, B, N | | | A, B, N and inverted channels | | |
| Output | Push-pull | | | | | |
| Lead | Max. 40 mA / channel | | | Max. 40mA / channel | | |
| Signal level | at 20 mA<br>H > $U_B$ – 2.5 VDC<br>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. 100mA | Typ. 40 mA | Typ.70 mA | | Typ. 100 mA | Typ. 40 mA |
| Channels | A, B, N | | | | A, B, N and inverted channels | | | |
| Output | push-pull | | | | | | | |
| Lead | Max. 40 mA / channel | | | Max. 30 mA / channel | Max. 40mA / channel | | | Max. 30 mA / channel |
| Signal level | at 20 mA<br>H > 2.5 VDC<br>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 | | |

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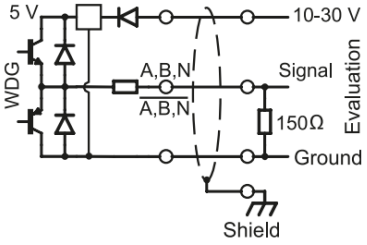
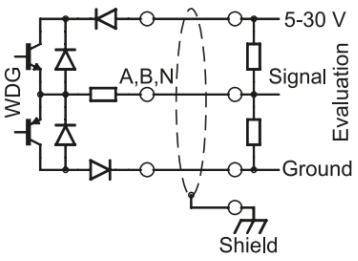
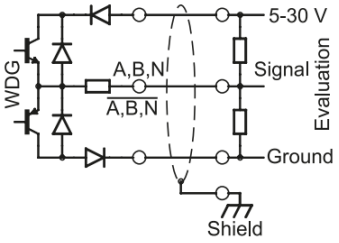
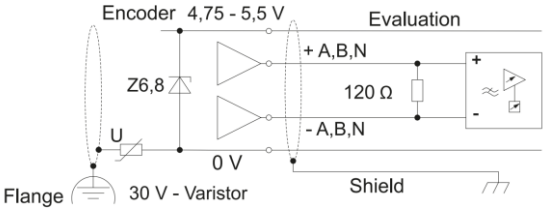
| Key | 245 (RS422 TTL) | 524 (RS422 TTL) | 645 (RS422 TTL) | N30 (HTL, TTL bei 5 VDC) | N35 (HTL, TTL bei 5 VDC) | H30 (HTL, TTL bei 5 VDC) | R30 (HTL, TTL bei 5 VDC) | M35 (HTL, TTL bei 5 VDC) | M30 (HTL, TTL bei 5 VDC) |
|---|---|---|---|---|---|---|---|---|---|
| Output circuit |  | | |  | | |  | | |
| 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 and inverted channels | | | A, B, N | | | A, B, N and inverted channels | | |
| Output | Push pull | | | | | | | | |
| Lead | Max. 40 mA / channel | | | Max. 30 mA / channel | Max. 40 mA / channel | | | | Max. 30 mA / channel |
| Signal level | at 20 mA<br>H > 2.5 VDC<br>L < 1.2 VDC | | | at 20 mA<br>H > $U_B$ – 10% $U_B$<br>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 | | | | | |

| Key | SIN / SIF (Sinus/ Cosinus) |
|---|---|
| Output circuit |  |
| 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 Vpp +/- 25% |
| Limit frequency (-3dB) | 100 kHz |
| Circuit protection | No |
| Light reserve warning | Circuit SIN: no<br>Circuit SIF: yes<br>(SIF: 80H and 100G/H/I) |
| Cable length | Max. 150m at <260 pF/m |