SCHAEFFLER

Schaeffler SpindleSense

Spindle monitoring by measuring displacement

Foreword

The machine building and equipment production sector is characterised by the trend towards intelligent, networked machines. It is becoming increasingly important to gain information about the operating mode of machinery. Wherever machine components move, there is a need for data on measurement values such as velocity, speed, force or temperature. The bearing position is often the ideal location for collecting these data. The high precision of rolling bearings and the accuracy of the adjacent construction facilitate high quality of measurement at this point.

Identifying critical machine conditions in good time is extremely important, particularly in machine tools. In addition to this, the captured process data help to optimise the production process further.

With Schaeffler SpindleSense, Schaeffler offers a very compact solution for main spindles and thus enables displacement measurement, which can be used in applications ranging from process monitoring through to the implementation of a closed-loop process control system. In addition, Schaeffler SpindleSense contains an integrated evaluation unit, which in combination with FAG spindle bearings and following adaptation of the evaluation algorithm to the spindle and machine, permits reporting of an overload on the spindle bearing arrangement.

Current product information always online

This edition of this publication describes the status of product information at the time of publication.

The current edition of TPI 258 is already available for download at:

- **www.schaeffler.de/std/1F33**.

Contents

Schaeffler SpindleSense

Features

Schaeffler SpindleSense is a compact measuring system for use in machine tools, which allows non-contact and high-precision measurement of the displacement between shaft and housing with high measurement frequency.

When used in combination with FAG spindle bearings, it is also possible to detect overloads. As a result, damage and resulting machine downtimes can be avoided.

Design

The sensor unit comprises a sensor ring and both an axial and a radial measurement ring.

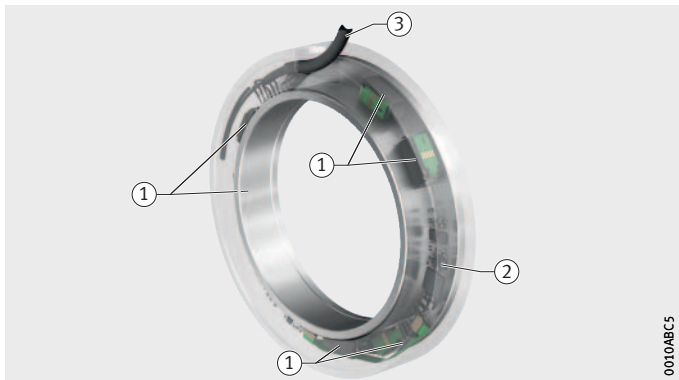
① Sensor unit

Sensor unit components:
② Sensor ring
③ Radial measurement ring
④ Axial measurement ring

Figure 1
Sensor unit

The sensor ring has the following integral components:

- 3 axially and 3 radially arranged eddy current distance sensors
- Evaluation unit (hardware and software)
- Connection cable for data exchange and voltage supply.



① Eddy current distance sensors
② Evaluation unit
③ Connection cable

Figure 2
Sensor ring
(image without module support and without cast material)

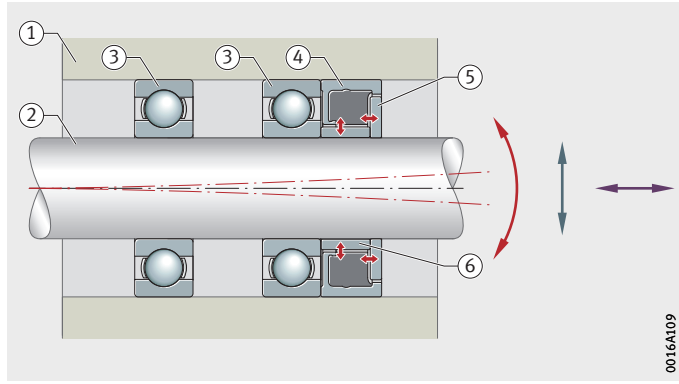
Materials

Components	Material
Sensor ring, measurement rings	100Cr6
Cast material	Epoxy resin
Cable sheath for connection cable	Polyurethane

Measurement principle

The distance sensors measure the axial and radial displacement between the sensor ring fixed in the housing and the measurement rings located on the shaft with a resolution of approximately 1 µm. The displacements and tilting determined by this method are outputted at a frequency of 1 kHz via CAN bus.

With appropriate parametrising, the evaluation unit integrated in the sensor ring also calculates the load on the bearing. For this purpose, the speed signal of the spindle must also be fed to the sensor ring. The evaluation unit then identifies critical conditions within 2 ms and sends these to the machine controller via the CAN bus and digital signal output.



① Housing
② Shaft
③ Bearing
④ Sensor ring
⑤ Axial measurement ring
⑥ Radial measurement ring

Figure 3
Displacement measurement

The displacement is caused by axial loading, radial loading, tilting and temperature. These influences must be taken into consideration in the interpretation of the measurement results.

To ensure the displacement measurement is interpreted correctly, it is essential that Schaeffler carry out a comprehensive analysis of the application.

Functional scope

Schaeffler SpindleSense is supplied as standard in a basic version with displacement measurement (functional scope: C-A1).

When used in combination with FAG spindle bearings, the function can be expanded to detect overloading of the spindle bearings. This requires an application-specific configuration of the sensor ring by Schaeffler.

Functional scope

Designation	Description
C-A1	Output for measured displacements (axial and radial) and tilting via CAN bus
Upgrade	Alarm message output, if limiting values for load or kinematics are exceeded

The functional scope is part of the ordering designation, see page 8.

Interfaces

Schaeffler SpindleSense has the interfaces shown in *Figure 4*, *Figure 5* and table:

- CAN bus as communications interface between the sensor ring and Windows PC and for the output of measurement data for further processing. Configuration software provides comprehensive setting options and allows software updates
- voltage supply
- alarm and error output
- speed signal inputs (HTL compatible).

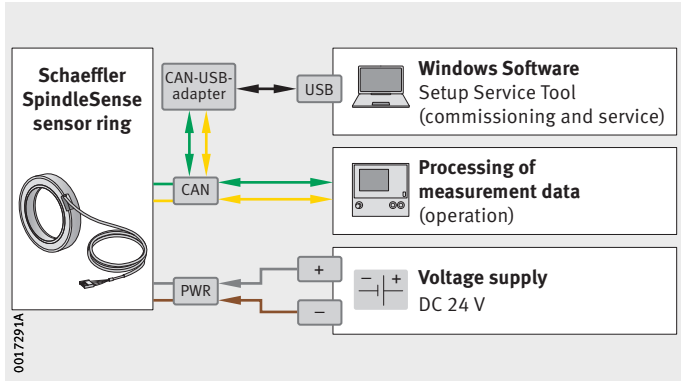


Figure 4
Interfaces
(functional scope: C-A1)

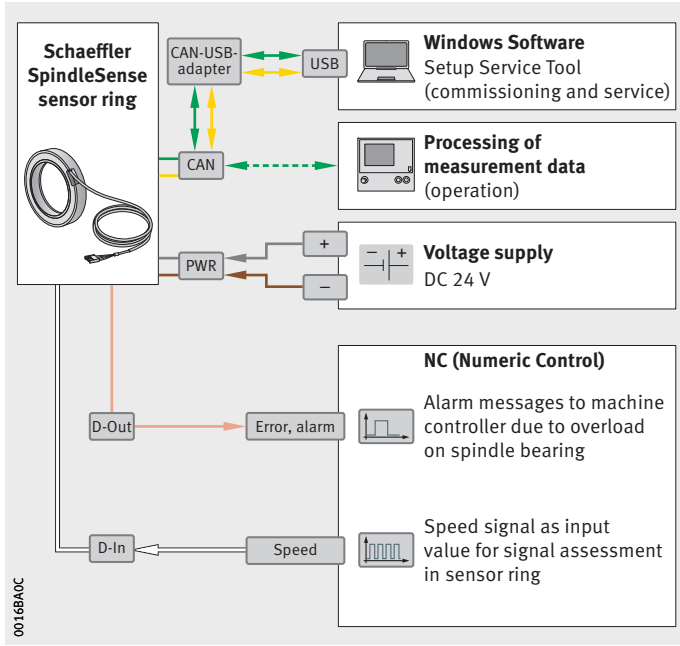


Figure 5
Interfaces
(functional scope: C-A1 + upgrade)

Interface characteristics

Name	Characteristic		
CAN	CAN bus		
	Symbol rate		1 MBd (high-speed CAN)
	Protocol		Proprietary
PWR	Voltage supply DC 24 V, see table, page 12		
D-Out	Digital output		
	Output voltage (signal type)	normal operation	24 V (constant)
		alarm (overload)	0 V (constant)
		error	0 V up to 24 V (square wave signal, 1 Hz)
	Output voltage (duration)	normal operation	Continuous
		alarm (overload)	Configurable
		error	For as long as the error remains[1)]
	Output current	permanent	50 mA
		maximum	100 mA
D-In	Digital input		
	Signal type		Speed (HTL compatible)
	Signal voltage		0 V up to 24 V (square wave signal)

1) Minimum duration = 50 ms.
During this time there is no signal output via the CAN bus.

Operating life

Schaeffler SpindleSense has a documented operating life of 18 000 hours.

The operating life was determined for a specific temperature spectrum, see table.

Temperature spectrum

Temperature °C	Time proportion of the operating life test %
0	1
+23	20
+40	69
+75	9
+80	1

Ordering designation

The structure of the ordering designation is shown in *Figure 6*.

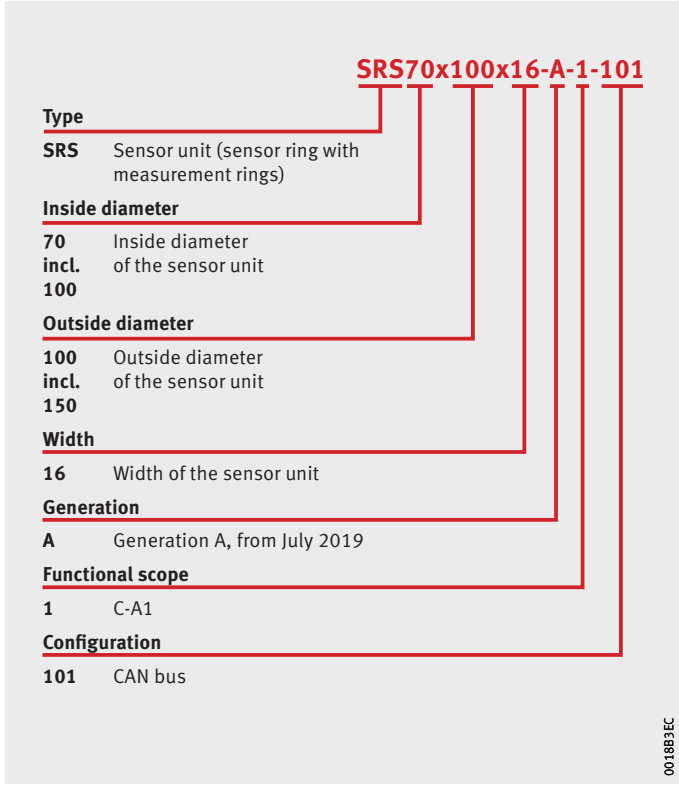


Figure 6
Ordering designation

Design and safety guidelines

Design of the bearing position

Schaeffler SpindleSense is installed in the immediate vicinity of Schaeffler spindle bearings. The requirements for the mounting position depend on the spindle bearing requirements.

Tolerances

The required machining tolerances for the shaft and housing when fitting Schaeffler SpindleSense are exactly the same as those required for the spindle bearings.

Note on Schaeffler SpindleSense tolerances:

- The tolerances for the sensor rings, the axial measurement rings and the radial measurement rings are based on the Schaeffler intermediate ring tolerances with the exception of the bore tolerances for the radial measurement rings.
- The radial measurement ring bore tolerances are based on the Schaeffler spindle bearing bore tolerances.

For more information on the tolerances for Schaeffler SpindleSense, see dimension table.

Further information

Tables with shaft and housing machining tolerances as well as tables with tolerances for Schaeffler spindle bearings and Schaeffler intermediate rings can be found in:

- Catalogue SP 1, Super Precision Bearings.

Stationary outer ring

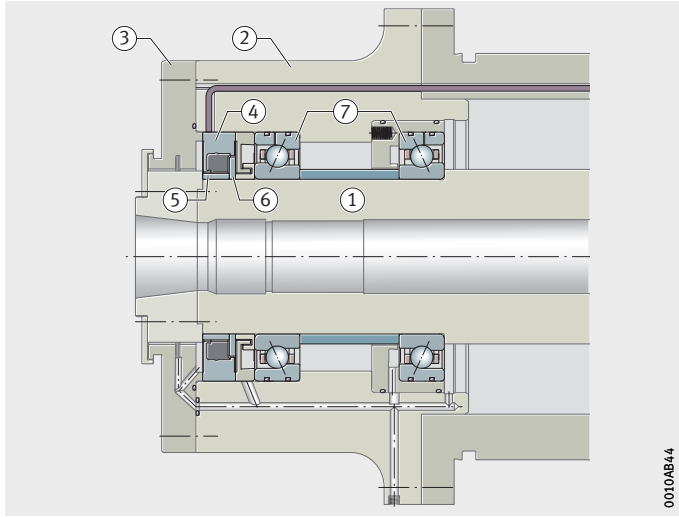
Schaeffler SpindleSense can only be used in applications with a stationary outer ring due to the cable connection arrangement.

An anti-rotation locking device is not required. The sensor ring is secured against rotation by the axial bracing.

Arrangement

The preferred installation position for Schaeffler SpindleSense is directly in front of the first bearing on the work side of the spindle, between the bearing and the tool interface, *Figure 7*.

Due to the extremely small distance between the sensor ring and the bearing, this arrangement leads to maximum accuracy when measuring the displacement and the subsequent calculation of the load on the bearing.



① Shaft
② Housing
③ Housing cover
④ Sensor ring
⑤ Radial measurement ring
⑥ Axial measurement ring
⑦ Bearing

Figure 7
Arrangement

For bearings with pneumatic oil lubrication, we recommend an intermediate ring through which the oil can pass.

Lubricants and coolants should not be guided through the gap between the sensor ring and the measurement rings on Schaeffler SpindleSense.

We recommend the cable is guided to the outside through the gap between the housing and the cover, *Figure 7*.

Designed to be easily dismantled

The construction is to be designed such that it is possible to dismantle the sensor ring and the measurement rings without any forces being transmitted through the casting for the sensor ring's electronics. The dismantling forces can be transmitted through the steel ring on the sensor ring.

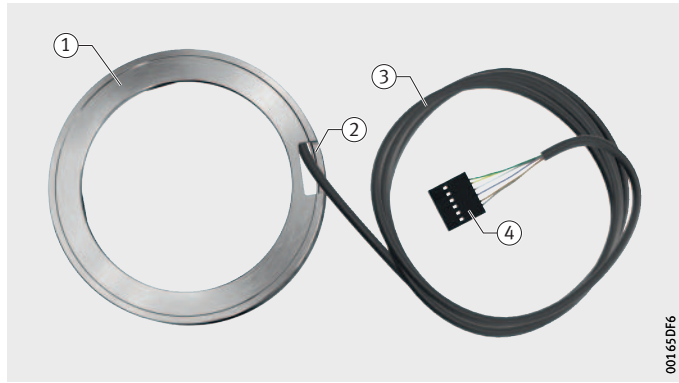
Transmitting the dismantling forces through the casting for the sensor ring's electronics can damage the electronics.

Connection

Schaeffler SpindleSense is supplied with a 6-pole, 2 m long connection cable which is not suitable for drag chain use, *Figure 8*.
Once the cable has been fitted into the spindle, it can be shortened to the required length.

The cable has a temporary connector for easy initial configuration and protection of the cords during transport. This connector should be removed and replaced with a suitable connector.

The cable outlet is designed such that the cable can be guided away from the sensor ring in an axial or radial direction.



① Sensor ring
② Cable outlet, axial and radial
③ Connection cable
④ Temporary connector and transport protection (to be removed)

Figure 8
Sensor ring with connection cable

The connection cable is designed with as small a cross section as possible so that it occupies the minimum amount of space once in place, see tables, page 11 and page 12.

Connection cable Technical data

Designation		Value
Type		Shielded sensor cable
Length		2 m
Cross-section area of conductor		6×0,093 mm^2
Outside diameter		3,8 mm ±0,15 mm
Minimum bending radius	static	7,4 mm (2 times the outside diameter)
	dynamic	19 mm (5 times the outside diameter)
Recommended bending radius	dynamic	38 mm (10 times the outside diameter)
Temperature range	static	–40 °C up to +80 °C
	dynamic	0 °C up to +80 °C
Mass		23 g/m
Material (cable sheath)		Polyurethane

Connection cable
Signal assignment of the cables

Signal	Cable	
	Colour	Number
Voltage supply	Grey	1
Ground	Brown	2
Digital output overload	Pink	3
Digital input speed	White	4
CAN low	Yellow	5
CAN high	Green	6
Shielding	–	–

Voltage supply

In addition to the internal fuse, an external fuse is required on the customer side for the voltage supply of the sensor unit, see table.

Voltage supply and fuse

Designation		Value
Supply voltage	nominal	DC 24 V
	tolerance	±4%
Power consumption	typical	60 mA at 24 V
	max.	100 mA at 24 V
Switch-on current		1,2 A
Internal fuse	self-resetting	
	typical operation	200 mA
	trip	500 mA up to 600 mA
External fuse	required, to be fitted by the customer	

Electromagnetic compatibility

In order to ensure electromagnetic compatibility, the connection cable is shielded.

Further information

Further information on electromagnetic compatibility and shielding:
- BA 61, Schaeffler SpindleSense – user manual.

Permissible indirect process materials

The resistance of the encapsulating material used in the sensor ring has been checked and confirmed for a selection of indirect process materials.

Indirect process materials to which the sensor unit is resistant

Type	Designation
Mounting paste	FAG ARCANOL-MOUNTINGPASTE
Oil for gearboxes and rolling bearings	Mobil SHC 626
Oil for gearboxes	OEST SYNTH SAE 75W-90
ASTM reference oil	IRM 902
Cooling lubricant	Emulcut 4020 (5%)
	Castrol Syntilo 81BF (5%)

Operating limits

Schaeffler SpindleSense is intended for use with machine tool spindles where there are no special protection requirements.

The exclusion criteria and ambient conditions stated below must be observed.

Exclusion criteria

Schaeffler SpindleSense may not be used in the following application areas:

- explosive environments (ATEX)
- nuclear power
- aerospace
- rail
- military
- medical equipment.

In addition to the areas of application that are explicitly excluded, Schaeffler SpindleSense may also not be used in any applications where the use of the measurement values has an influence on the safety of the machine itself, any adjacent systems, or people.

Ambient conditions

Air pressure:

- The permissible ambient pressure range is 700 hPa up to 1050 hPa.

Temperature:

- The permissible ambient temperature range is 0 °C up to 80 °C.

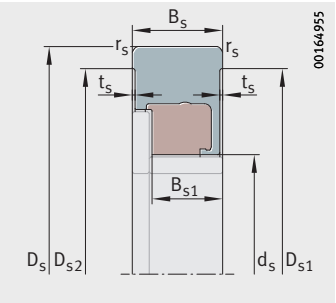
Protection type in accordance with ISO 20653:

- The sensor and interface unit are designed in accordance with the protection type IP65.

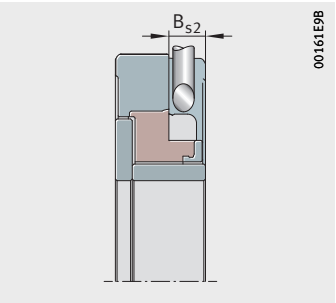
Excluded ambient conditions:

- Magnetically or electrically conductive dusts or particles.

Schaeffler SpindleSense



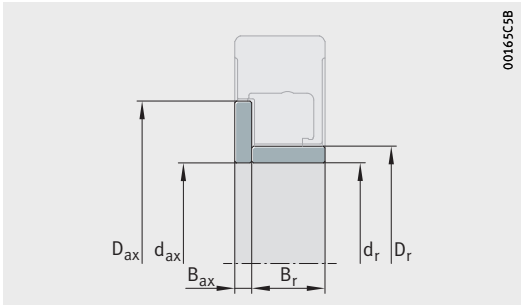
Sensor ring



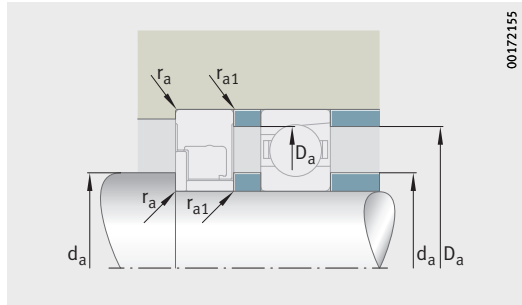
Cable outlet

Dimension table · Dimensions in mm

Designation		Mass	Dimensions						
			Sensor ring						
for spindle bearings		m	d_s	D_s	B_s	B_{s1}	r_s	D_{s1}	D_{s2}
Series 719	Series 70	≈ kg					min.		
SRS70X100X16-A	–	0,45	76,4	$100\ ^{-0,012}_{-0,034}$	$16\ ^{0}_{-0,1}$	$12,5\ ^{+0,1}_{-0,4}$	1	94,65	92,4
–	**SRS70X110X16-A**	0,65	76,4	$110\ ^{-0,012}_{-0,034}$	$16\ ^{0}_{-0,1}$	$12,5\ ^{+0,1}_{-0,4}$	1,1	102,15	102,15
SRS80X110X16-A	–	0,55	86,7	$110\ ^{-0,012}_{-0,034}$	$16\ ^{0}_{-0,1}$	$12,5\ ^{+0,1}_{-0,4}$	1	104,15	102,7
–	**SRS80X125X16-A**	0,87	86,7	$125\ ^{-0,014}_{-0,039}$	$16\ ^{0}_{-0,1}$	$12,5\ ^{+0,1}_{-0,4}$	1,1	117,15	117,15
SRS100X140X16-A	–	0,89	110,8	$140\ ^{-0,014}_{-0,039}$	$16\ ^{0}_{-0,1}$	$12,5\ ^{+0,1}_{-0,4}$	1,1	133,2	133,2
–	**SRS100X150X16-A**	0,9	110,8	$150\ ^{-0,014}_{-0,039}$	$16\ ^{0}_{-0,1}$	$12,5\ ^{+0,1}_{-0,4}$	1,5	141,2	141,2



Measurement rings



Mounting dimensions

		Axial measurement ring			Radial measurement ring			Mounting dimensions			
t_s	B_{s2}	d_{ax}	D_{ax}	B_{ax}	d_r	D_r	B_r	d_a h12	D_a H12	r_a max.	r_{a1} max.
0,5	6,5	70 $^{+0,04}_{+0,03}$	91,6	3 $^{0}_{-0,05}$	**70** $^{\mathbf{0}}_{\mathbf{-0,007}}$	75,6	13 $^{0}_{-0,05}$	76	94,5	0,3	1,9
0,5	6,5	70 $^{+0,04}_{+0,03}$	91,6	3 $^{0}_{-0,05}$	**70** $^{\mathbf{0}}_{\mathbf{-0,007}}$	75,6	13 $^{0}_{-0,05}$	77	102	0,3	2
0,5	6,5	80 $^{+0,04}_{+0,03}$	101,9	3 $^{0}_{-0,05}$	**80** $^{\mathbf{0}}_{\mathbf{-0,007}}$	85,9	13 $^{0}_{-0,05}$	86	104	0,3	1,9
0,5	6,5	80 $^{+0,04}_{+0,03}$	101,9	3 $^{0}_{-0,05}$	**80** $^{\mathbf{0}}_{\mathbf{-0,007}}$	85,9	13 $^{0}_{-0,05}$	88	117	0,3	2
0,5	6,5	100 $^{+0,04}_{+0,03}$	128	3 $^{0}_{-0,05}$	**100** $^{\mathbf{0}}_{\mathbf{-0,008}}$	110	13 $^{0}_{-0,05}$	107	133	0,3	2
0,5	6,5	100 $^{+0,04}_{+0,03}$	128	3 $^{0}_{-0,05}$	**100** $^{\mathbf{0}}_{\mathbf{-0,008}}$	110	13 $^{0}_{-0,05}$	110	141	0,3	2,3

Request for parametrisation of Schaeffler SpindleSense

Schaeffler Technologies AG & Co. KG Georg-Schäfer-Strasse 30 · 97421 Schweinfurt · Germany ·
www.schaeffler.de · spindlesense@schaeffler.com

Customer: _____

Contact: _____

Machine type:
- ❑ Car production
- ❑ Tooling and mould production
- ❑ Universal machine
- ❑ High-performance milling, turning and grinding
- ❑ High-speed machining

Drive system:
- ❑ Motor spindle, direct drive
- ❑ Belt drive
- ❑ Threaded spindle
- ❑ Inline spindle

Application objective:
- ❑ Overload detection
- ❑ Displacement measurement
- ❑ Displacement compensation
- ❑ Monitoring of bearing load

Drawing attached: ❑ yes ❑ no

Bearing arrangement (diagram, for example << >):

Shaft position:
- ❑ vertical
- ❑ horizontal
- ❑ swivelling

- ❑ rigid
- ❑ spring-adjusted

Spring force _____

Spring rigidity _____

Bearing type(s) working side (front): _____

working side (rear): _____

Bearing diameter, working side inside: _____ mm

outside: _____ mm

Maximum speed: _____ min^{-1}

Lubrication: _____

Nominal viscosity: _____ $mm^2 \cdot s^{-1}$

Load cycles

Forces			Speed	Time portion	Tool diameter	Boom	Belt tension, drive
F_r	F_a	F_t				a	F_R
kN	kN	kN	min^{-1}	%	mm	mm	kN

Special environmental influences, operating conditions:

Assumptions:

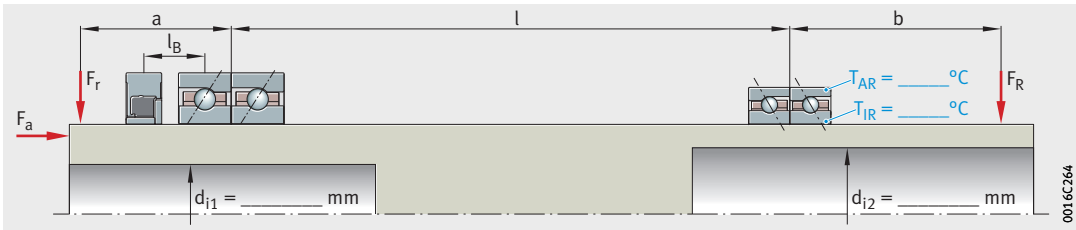
Bearing operating temperature	front, rear:	T =	_____ , _____	°C
ΔT (inner ring/outer ring)	front, rear:		_____ , _____	K
Interference (shaft/inner ring)	front, rear:		_____ , _____	µm
Clearance fit (outer ring/housing)	front, rear:		_____ , _____	µm

Bearing spacing l: _____ mm

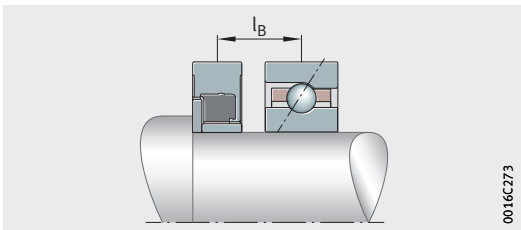
l_B: _____ mm

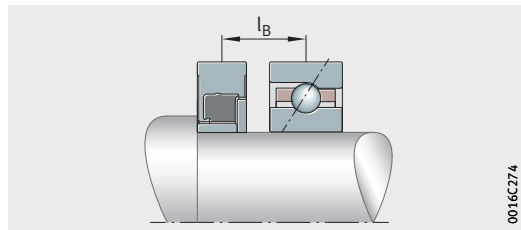
Drive spacing b: _____ mm

Boom a: _____ mm, see table



Installation direction: ❑ Variant 1 ❑ Variant 2





Anticipated quantity per year:

Questions
(please attach drawings if possible):

Contact: Date:

Please send the completed form to spindlesense@schaeffler.com

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