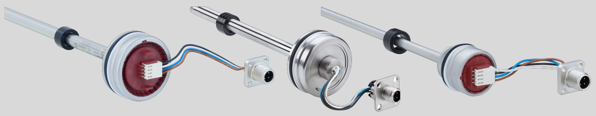
OPERATING INSTRUCTIONS

MAX®

Linear encoder

SICK
Sensor Intelligence.



Product described

MAX® linear encoder

Manufacturer

SICK AG
Erwin-Sick-Str. 1
79183 Waldkirch
Germany

Legal information

Original document

This document is an original document of SICK AG.

Contents

1 About this document

1.1 Purpose of this document

In the following instructions, the MAX® linear encoder is referred to simply as “encoder” or “device”.

These operating instructions describe:

- Device components
- Mechanical preparation of the device
- Electrical preparation of the device
- Necessary maintenance work for safe operation

1.2 Target audience

This document is intended for technicians (persons with technical expertise) tasked with installing and maintaining the device.

These technicians must be trained on the device.

Only trained electricians are permitted to carry out work on the electrical system or electrical assemblies.

1.3 Further information

- MAX® quickstart
- Technical information - interface description

MAX® product pages

- www.sick.com/MAX®

1.4 Symbols and document conventions

1.4.1 Warning levels and signal words

Important

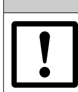
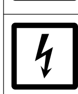
Hazard which could result in property damage.

Note

Tips

1.4.2 Information symbols

Table 1: Information symbols

Icon	Meaning
	Important technical information for this product
	Important information about electrical or electronic functions

2 Safety information

2.1 General notes

Should humans be at risk, or operating equipment potentially be damaged in the event of a malfunction or failure of the device, this must be prevented by means of suitable protective devices, e. g., emergency shutdown systems.

If the device is not functioning correctly, it must be taken out of operation and secured against unauthorized operation.

To guarantee proper operation of the device, please observe the following:

- Protect the device against mechanical stress during installation
- Do not open the device
- Connect the device with the correct polarity, supply voltage and control pulses
- Observe the permissible operating and ambient conditions for the device
- Regularly check the device for correct operation and document the results

2.2 Intended use

2.2.1 Purpose of the device

The MAX® linear encoder is designed for position measurements in mobile hydraulic applications (e.g. in hydraulic cylinders) and can be used to control the hydraulic components of self-driving mobile machines. The rugged housing offers optimum protection against dust, climatic influences, vibrations, surrounding media, as well as electrical and magnetic fields.

The device is a component and must be connected to a suitable electronic control unit. The MAX® linear encoder fulfills the requirements of the following EMC standards:

MAX30N:
- EN ISO 14982:2009 and EN ISO 13766-1:2018

MAX48N/MAX48A/MAXH1A/F1A:
- EN ISO 14982: 2009 / EN 13309: 2010 / EN ISO 13766-1:2018
- EN 61000-6-2: 2005 / EN 61000-6-3: 2011

2.3 Responsibility of user

Designated users

see "Target audience", page 6.

Correct project planning

- This document assumes that appropriate project planning has been carried out before delivery of the device (e.g., based on the SICK application questionnaire), and the device is in the required delivery state based on that planning (see supplied system documentation).
  - ▶ If you are not certain whether the device corresponds to the state defined during project planning or in the supplied system documentation, please contact SICK Customer Service.

Special local conditions

In addition to the instructions in this Technical Information, follow all local laws, technical rules and company-internal operating directives applicable at the respective device installation location.

Read the operating instructions

- Read and follow the operating instructions in this document
- Follow all safety notes
- If there is anything you do not understand, please contact SICK Customer Service

Retention of documents

These operating instructions:

- Must be made available for reference.
- Must be conveyed to new owners.

3 Product description

3.1 Device variants

The device is currently available in these variants:

MAX30N	MAX48N	MAX48A

Each device variant is available with the following interfaces and connection types:

Analog	PWM	Digital
M12 male connector, 4-pin 3-wire connecting cable		M12 male connector, 5-pin

Output signals

- Analog (current, voltage)
- PWM (pulse width [%] / frequency [Hz])
- Digital (CANopen, SAE J1939)

NOTE

See product pages of the MAX® www.sick.com/MAX® or:

- MAX48N product information: 8021725
- MAX48A product information: 8025847
- MAX30N product information: 8024964

3.2 Product identification

Type code

Table 2: Type code (example)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
M	T	X	4	8	N	-	1	1	R	1	0	T	T				

Table 3: Type code description (example)

Position	Meaning	Description
1	Series	M = Mobile
2	Technology	A = Magnetostrictive
3	Installation type	X = Integrated (hydraulic cylinder)
4	Size	48 = MAX48 diameter 30 = MAX30 diameter
5		
6	Version	N = radial cable routing/plug connector A = axial cable routing/plug connector
7	Place holder	-
8	Pipe diameter / damping / end cap	1 = 10 mm / 30 mm / flat 2 = 10 mm / 36 mm / flat 3 = 10 mm / 63 mm / flat 7 = 7 mm / 30 mm / flat[1)] 8 = 7 mm / 36 mm / flat[1)] 9 = 7 mm / 63 mm / flat[1)]
9	Supply voltage	1 = 12 VDC 2 = 24 VDC

1) MAX30 only

Position	Meaning	Description
10	Communication interface	V = Voltage A = Current C = Digital CANopen (250 kbit) J = Digital SAE J1939 (250 kbit) P = pulse-width modulation, 5 V signal
11 12	Signal output	10 = current (4 ... 20 mA) 10 = voltage (0.50 ... 4.50 V) 21 = voltage (4.75 ... 0.25 V) 7F = CANopen (node ID 7F Hex) FD = SAE J1939 (source address JD Hex) B = pulse width (10 ... 90%) D = frequency (250 Hz)
13	Connection type	A = M12 4-pin analog / PWM (1 = V DC; 2 = n.c.; 3 = GND; 4 = SIG) B = M12 4-pin analog / PWM (1 = V DC; 2 = SIG; 3 = GND; 4 = n.c.) M= M12 4-pin analog (1 = n.c.; 2 = V DC; 3 = GND; 4 = SIG) K = analog cable connection / PWM 3-wire cable C = M12 5-pin digital (1 = n.c.; 2 = V DC; 3 = GND; 4 = CAN_HI; 5 = CAN_LO) D = M12 5-pin digital (1 = V DC; 2 = n.c.; 3 = GND; 4 = CAN_HI; 5 = CAN_LO)
14	Connector length	A = strands, 60 mm 1 = connecting cable, 300 mm
15	Measuring range Position measurement in 1 mm steps	e.g., 0300 = 50 ... 300 mm
16		
17		
18		

3.3 Construction and function

Construction of the device

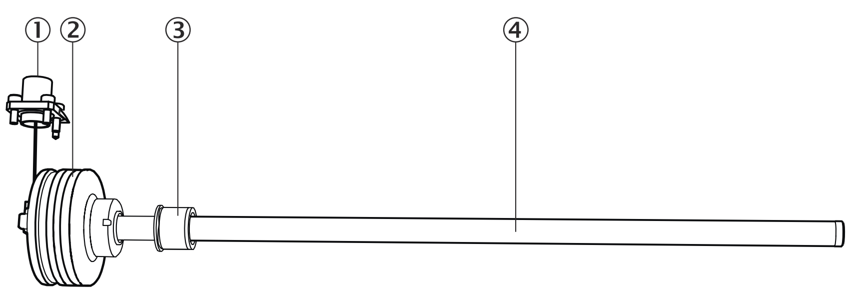


Figure 1: MAX® design

① M12 connector system
② Encoder housing (electronics)
③ Position magnet
④ Pressure pipe

Male connector system:
The M12 male connector system requires very little time to attach. It is suitable for applications in harsh environments up to IP69K (when using a suitable mating connector).

Encoder housing (electronics):
The housing is designed to be installed in a hydraulic cylinder and protects the electronics against external influences.

Position magnet:
The position magnet is the only moving component in the measuring device when installed in the piston. The position magnet is located inside the piston and moves over the pressure pipe without contacting it. The magnet field that is produced during this process defines the current position of the piston.

Pressure pipe:
The pressure pipe is a pressure-resistant structure that is immersed into the cylinder piston rod. It contains the hermetically protected magnetostrictive sensing element.

Principle of operation

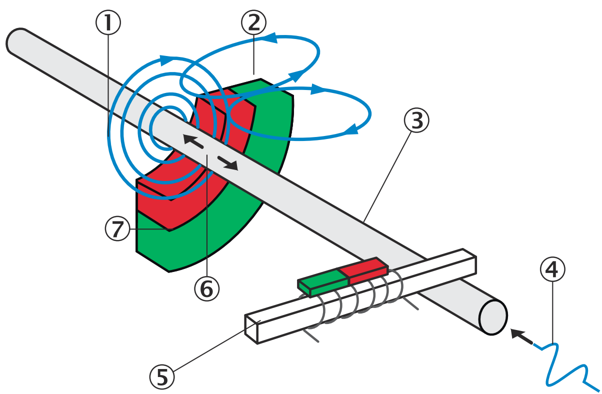


Figure 2: Schematic of the magnetostrictive measurement principle

① Magnet field of the current pulse
② Magnet field of the position magnet
③ Magnetostrictive sensor component
④ Current pulse
⑤ Sound wave converter
⑥ Structure-borne sound wave
⑦ Position magnet

The device operates on the magnetostrictive measurement principle that records the actual path of a position magnet:

The radial magnet field (1) generated by the current pulse (4) interacts with the magnet field (2) of the position magnet (7).

As a result of the interaction of the two magnet fields, a wave (ultrasonic) (6) is produced in the magnetostrictive device component (3). This travels to the converter (5), and the electronics produce an electrical output signal.

The time interval between the current pulse and the detection of the structure-borne sound wave is measured, thereby enabling the precise position of the magnet – which changes as the cylinder moves – to be determined. As this measurement principle does not require a reference point, no recalibration is necessary for this type of device.

The device is also maintenance-free as a result of the non-contact measurement.

4 Mounting

4.1 Preparation and installation of the encoder

The method of installation depends on the cylinder design. Installation is typically done by inserting it into the cylinder pipe. The encoder housing is inserted into the cylinder base. If the cylinder base is screwed or flanged to the cylinder pipe, installation via the base side is also possible. This is particularly advantageous for extended stroke lengths. Encoders with a flange housing (MAXFx) or with a screw-in housing (MAXHx) are also inserted and fastened in the cylinder from the bottom side.

The encoder dimensions are listed in the technical data: see "Encoder dimensions", page 54.

Recommended installation position:

MAX48N:

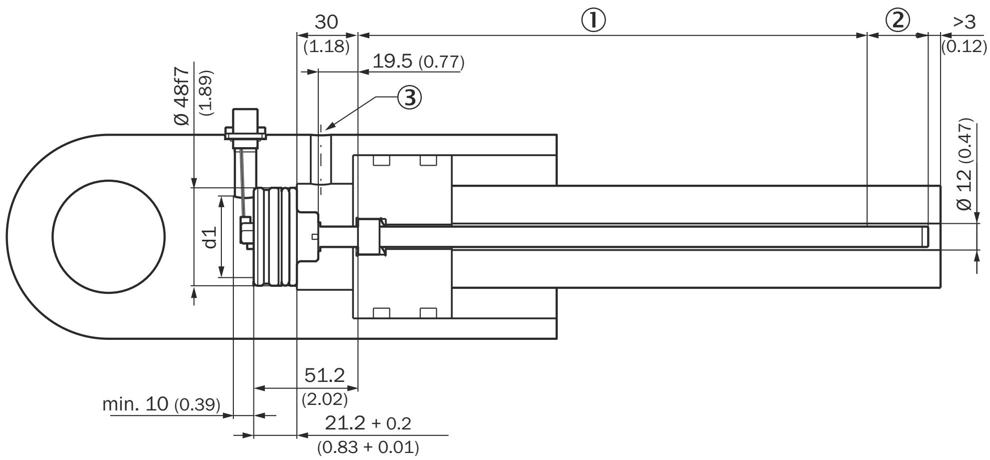


Figure 3: Encoder installed in the hydraulic cylinder, MAX48N with M12 male connector system

① Measuring range

② Damping zone

③ Hydraulic port

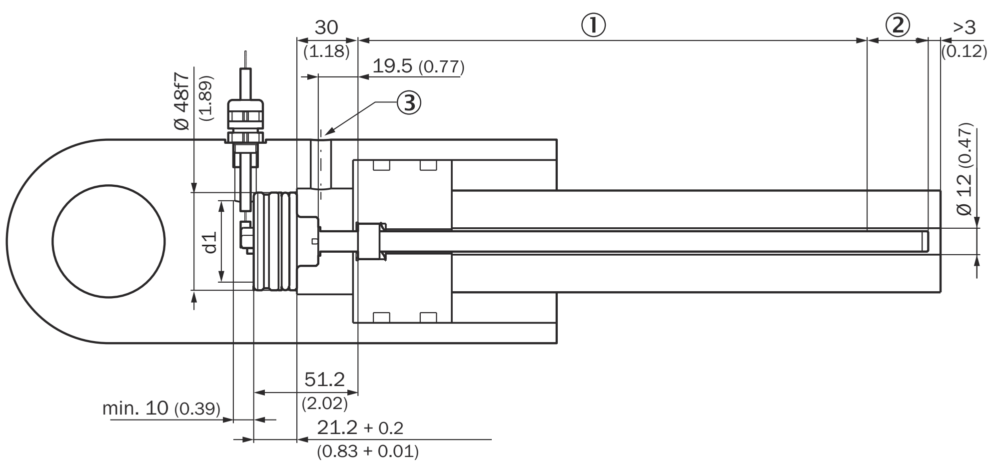


Figure 4: Encoder installed in the hydraulic cylinder, MAX48N with connecting cable

① Measuring range

② Damping zone

③ Hydraulic port

MAX48A:

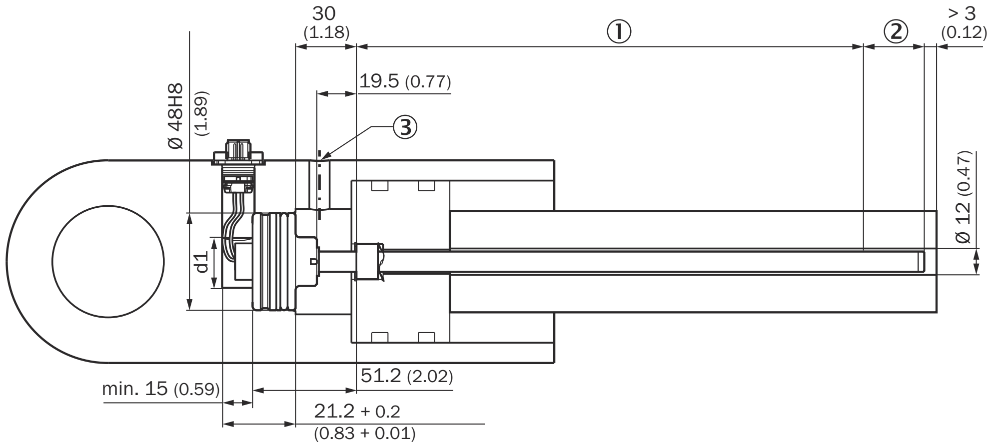


Figure 5: Encoder installed in the hydraulic cylinder, MAX48A with M12 male connector system

① Measuring range
② Damping zone
③ Hydraulic port

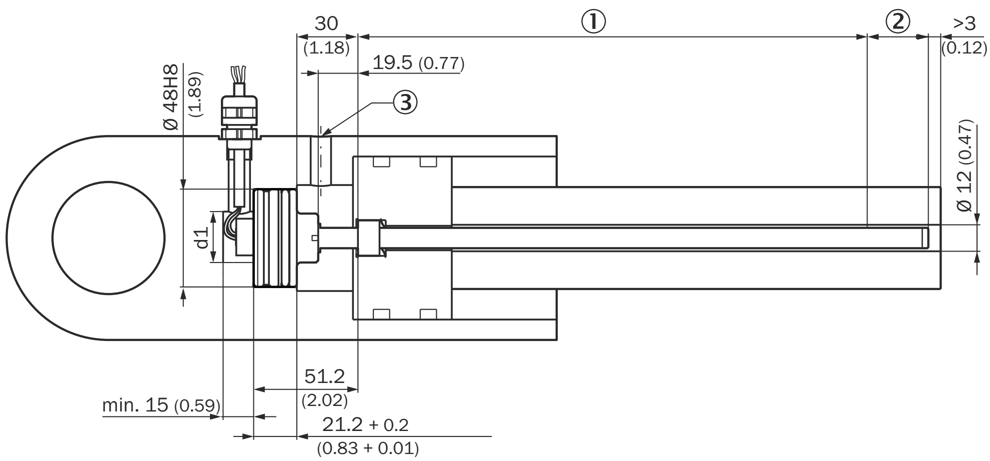


Figure 6: Encoder installed in the hydraulic cylinder, MAX48A with connecting cable

① Measuring range
② Damping zone
③ Hydraulic port

MAX30N:

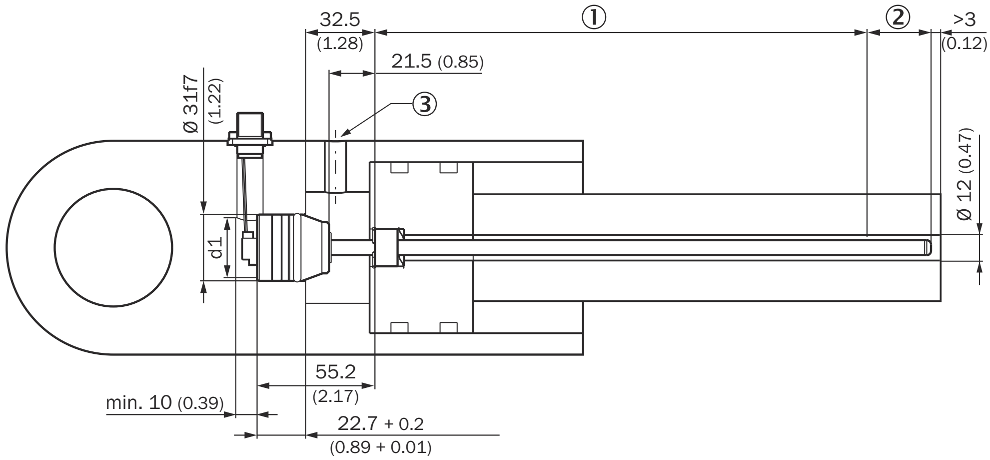


Figure 7: Encoder installed in the hydraulic cylinder, MAX30N with M12 male connector system

① Measuring range
② Damping zone
③ Hydraulic port

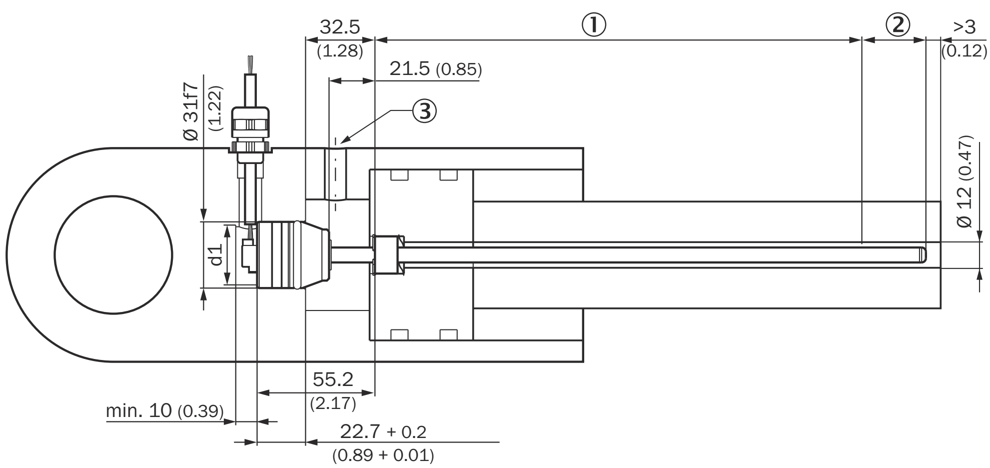


Figure 8: Encoder installed in the hydraulic cylinder, MAX30N with connecting cable

① Measuring range
② Damping zone
③ Hydraulic port

4.2 Installation cavity for encoder housing

4.2.1 Installation cavity in cylinder base

Fit dimensions and tolerances

Prepare an installation cavity for the encoder housing and electrical connection according to the following dimensions:

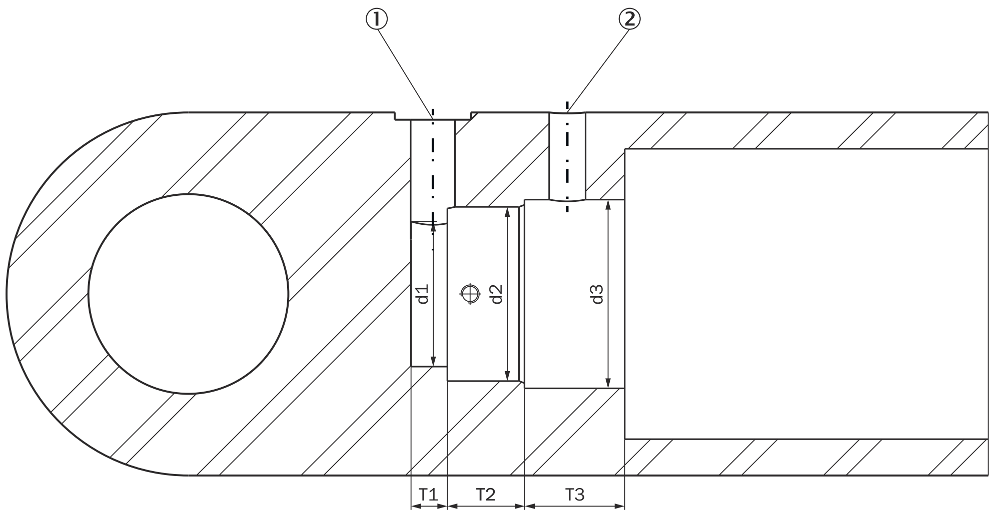


Figure 9: Dimensions for installation cavity of encoder housing

① Installation cavity for electrical connection

② Hydraulic port

Table 4: Installation cavity for the encoder housing and electrical connection

Type	Installation cavity for electrical connection		Installation cavity for encoder housing		Null zone	
	(d1) Ø	(T1) depth	(d2) Ø	(T2) depth	(d3) Ø	(T3) depth
MAX48N	32<=d1<=40	>=10	48 H8	21.2 $^{+0.2}$	>=52	>=28
MAX48A	25<=d1<=40	>=15	48 H8	21.2 $^{+0.2}$	>=52	>=28
MAX30N	26<=d1<=28	>=10	31 H8	22.7 $^{+0.2}$	>=35	>=30

Mean roughness value of the surface: Ra < 0.8 mm

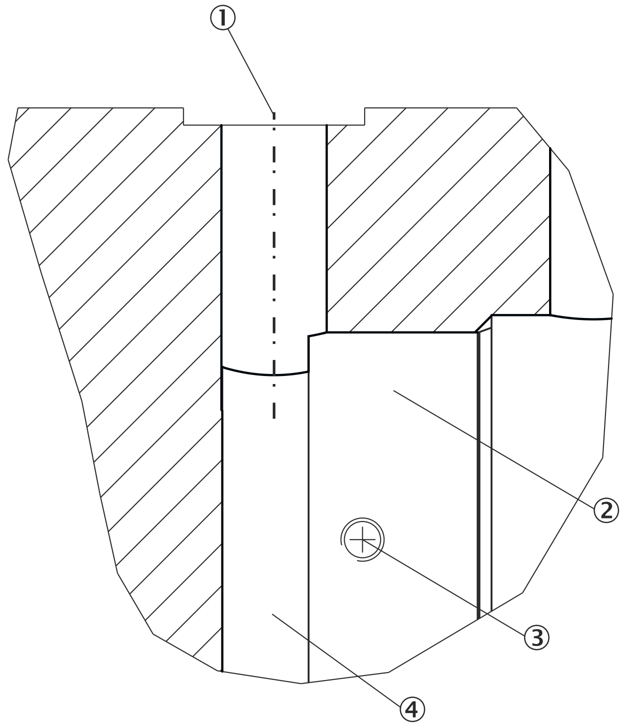


Figure 10: Detailed view of installation cavity for encoder housing

① Bore hole for passing through the electrical connecting cable
② Installation cavity for encoder housing (d2 and T2)
③ Threaded hole for the retaining screw
④ Diameter (d1) and depth (T1) of electrical connection

4.2.2 Insertion chamfer

To ensure proper and secure installation of the device in the cylinder, a insertion chamfer must be provided.

NOTICE
Risk of damage to the device during installation
The device can be damaged by any sharp edges present at the transition from the cylinder bore hole to the insertion chamfer on the O-ring.

- Prepare an insertion chamfer with a radius of 0.6 mm at the end of the cylinder bore hole.

MAX48N and MAX48A

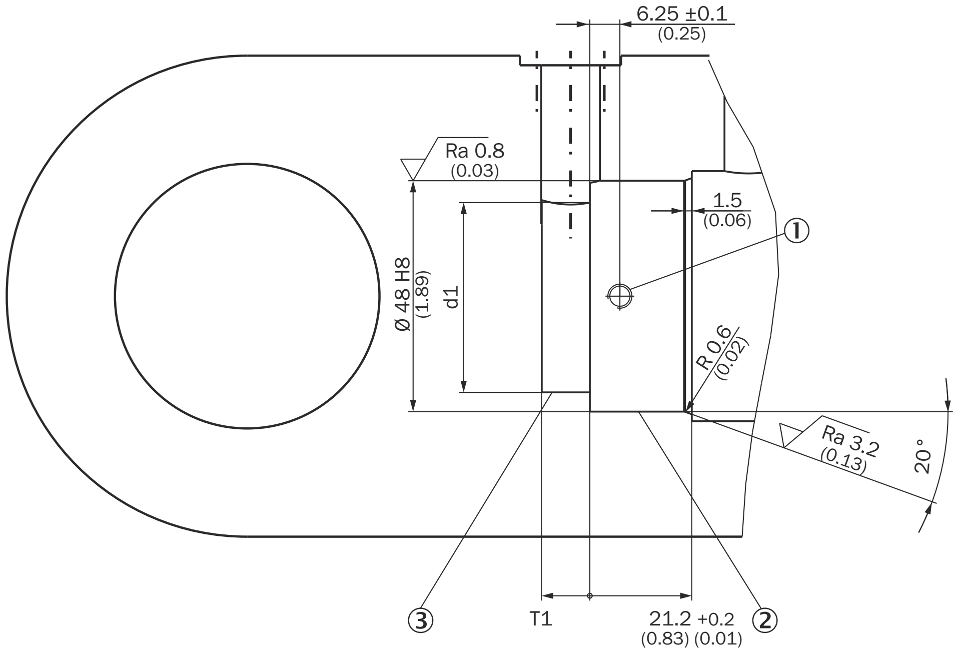


Figure 11: Introduction chamfer MAX48N and MAX48A

① Retaining screw
② Installation cavity for encoder housing
③ Installation cavity for electrical connection

MAX30N

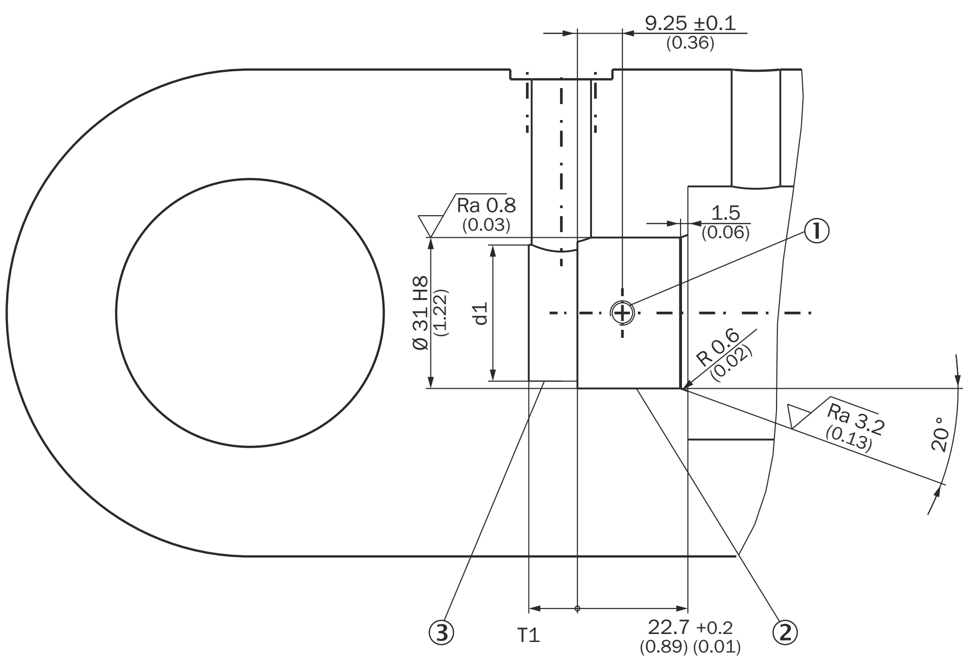


Figure 12: Introduction chamfer MAX30N

① Retaining screw
② Installation cavity for encoder housing
③ Installation cavity for electrical connection

4.2.3 Bore hole for M12 male connector system and cable gland

4.2.3.1 M12 flange type S

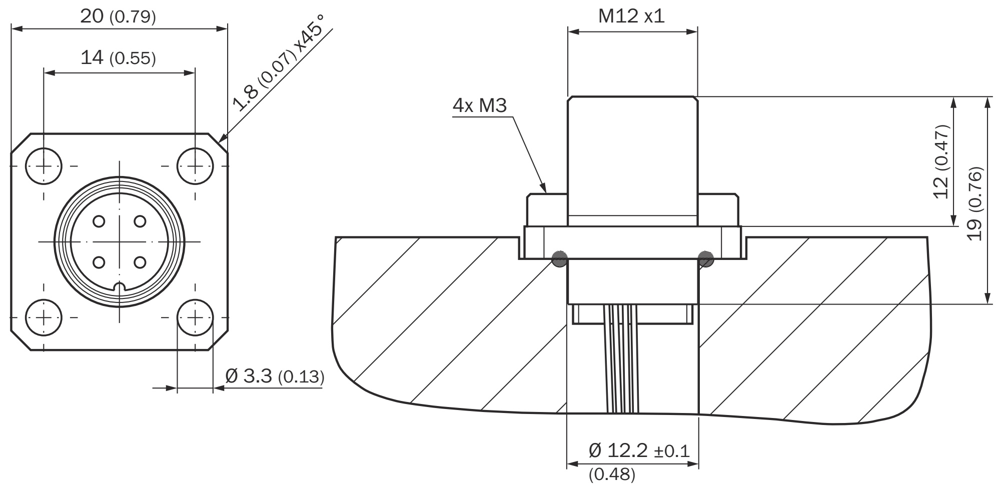


Figure 13: M12 flange type S installation situation

Prepare an installation cavity for the male connector system and flange plate in accordance with the following dimensions:

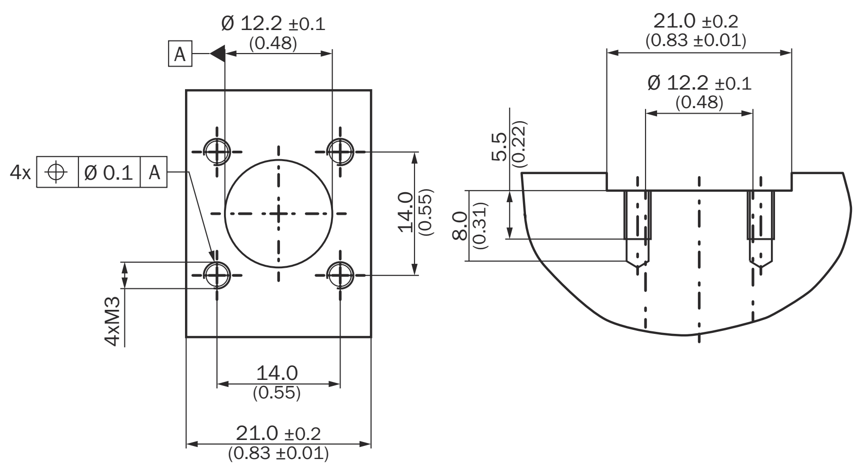


Figure 14: Prepare an installation cavity for the male connector system and flange plate M12 flange type S

4.2.3.2 M12 flange type L

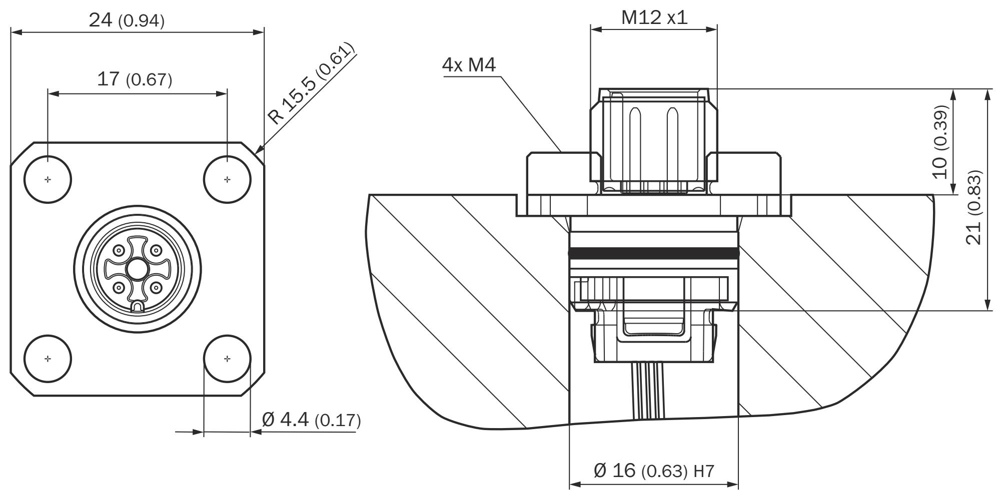


Figure 15: M12 flange type L installation situation

Prepare an installation cavity for the male connector system and flange plate in accordance with the following dimensions:

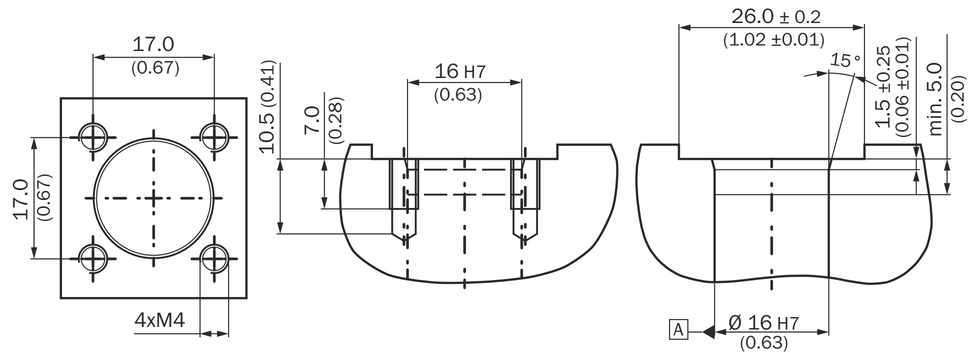


Figure 16: Prepare an installation cavity for the male connector system and flange plate M12 flange type L

4.2.3.3 Cable gland

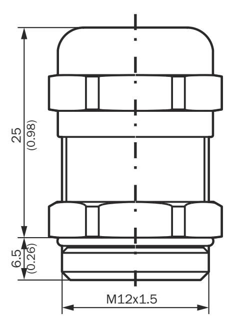


Figure 17: Cable gland

Cable gland with M12 x 1.5 connection thread, polyamide V0 terminal insert in accordance with UL94, NBR O-ring, NBR molded seal, width across flats 14

Prepare an installation cavity for the cable gland according to the following dimensions:

NOTICE
Prepare bore hole with thread and plane surface in accordance with figure 18

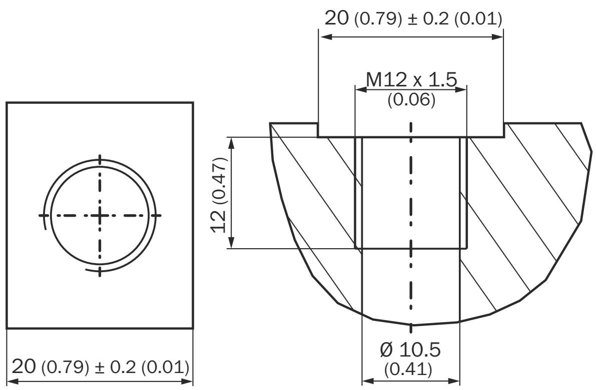


Figure 18: Preparation for cable gland installation hole

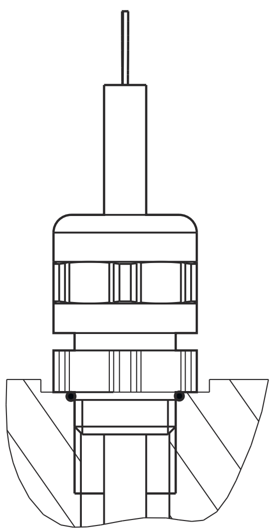


Figure 19: For installation with cable gland

4.2.4 Bore hole for the retaining screw

Prepare a bore hole for the retaining screw in accordance with the following dimensions:

MAX48N and MAX48A

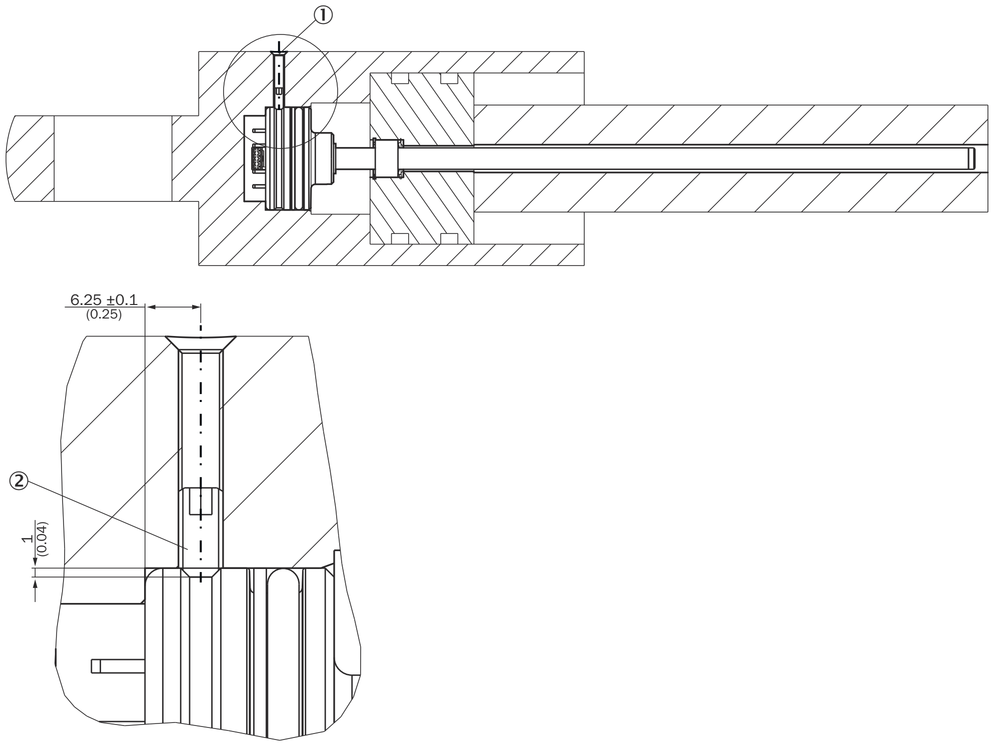


Figure 20: Bore hole for the retaining screw, MAX48N and MAX48A

① Retaining screw

② Detailed view of retaining screw (M5 screw DIN913)

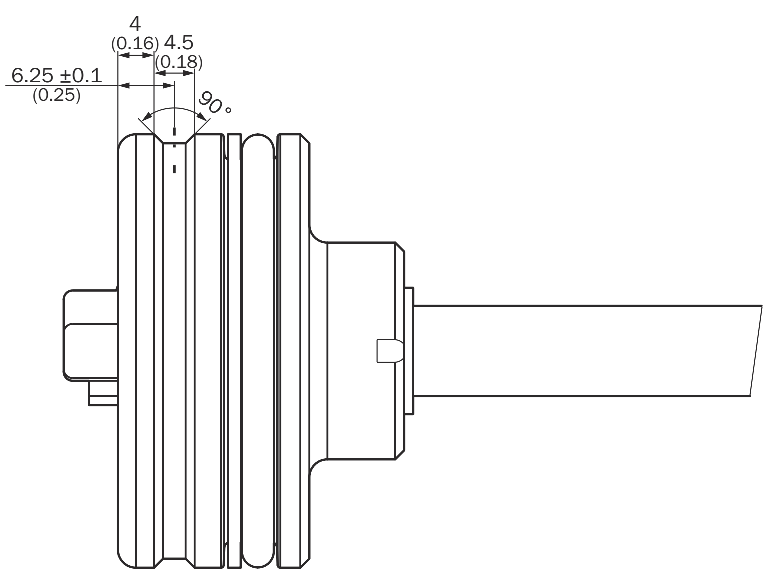


Figure 21: Detailed view of the slot for positioning the retaining screw

Permissible tightening torque for fastening screw: 0.5 Nm – 1.0 Nm (taking into account the maximum force on the housing surface).

MAX30N

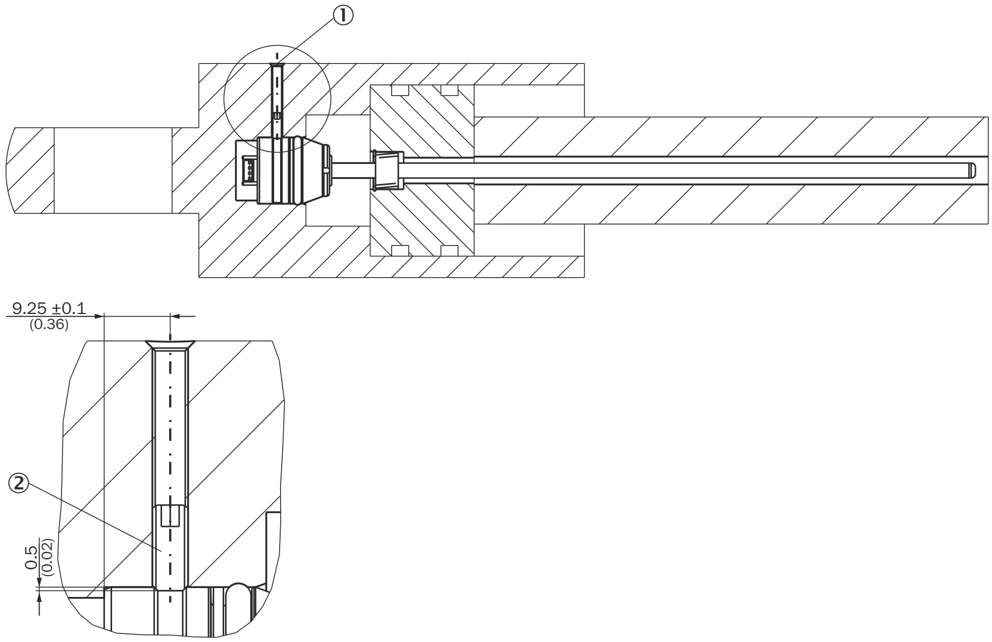


Figure 22: Bore hole for the retaining screw, MAX30N

① Retaining screw

② Detailed view of the retaining screw

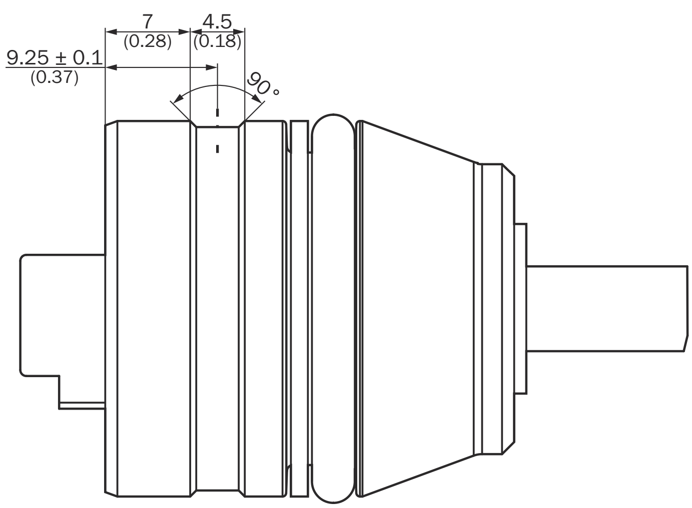


Figure 23: Detailed view of the slot for positioning the retaining screw

Permissible tightening torque for fastening screw: 0.5 Nm – 1.0 Nm (taking into account the maximum force on the housing surface).

4.3 Installation cavity for the piston and piston rod

4.3.1 Bore hole for piston

Prepare an installation cavity for the position magnet in accordance with the following dimensions:

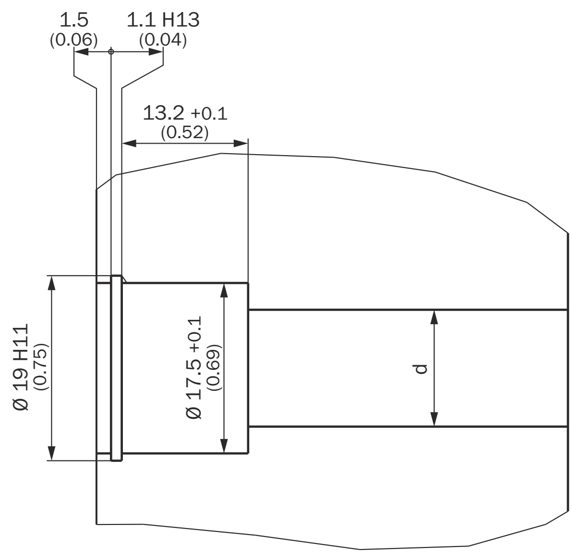


Figure 24: Dimensions of the position magnet installation cavity

Table 5: Diameter of the piston rod bore hole

Device type	Diameter d of bore hole for piston rod
MAX48N	12 mm
MAX48A	12 mm
MAX30N	10 mm

4.3.2 Piston rod bore hole

Prepare an installation cavity for the pressure pipe of the encoder in accordance with the following dimensions:

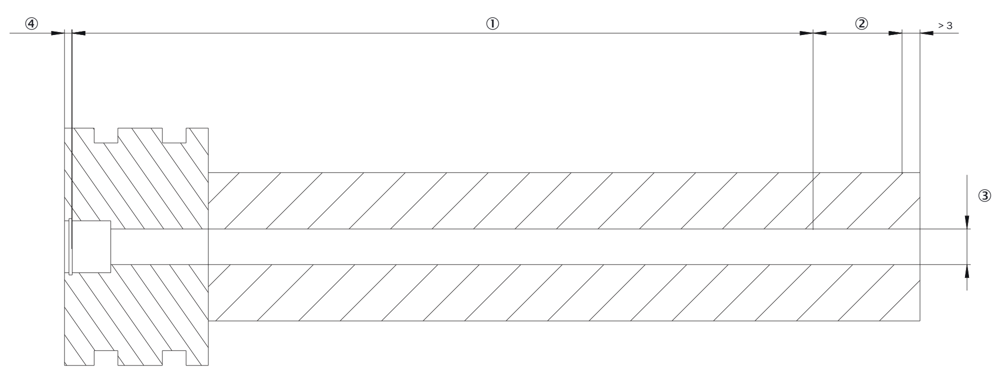


Figure 25: Piston and piston rod

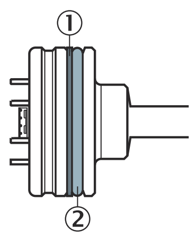
① Measuring range
② Damping zone (depending on type)
③ Diameter of the piston rod bore hole (depending on type)
④ Nullzone

Table 6: Bore hole depth of piston rode and installation cavity for electrical connection

Null zone	**MAX48: 30.0 mm** **MAX30: 21.5 mm**
Measuring range	As per the applicable data sheet and selected device variant
Damping	

NOTE
The total bore hole depth comprises the measuring range ①, the damping ②, and an addition distance of 3 mm to the pressure pipe. Bore hole diameter (d) in the piston rod is in accordance with see figure 10 (depending on type).

4.4 Encoder installation



① Support ring
② O-ring

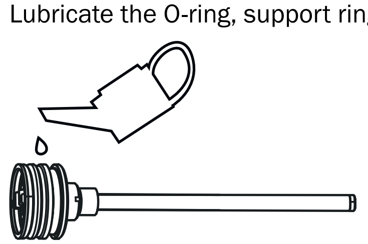
The O-ring and support ring are pre-installed as shown in the figure and prevent oil from penetrating into the connector area.

NOTICE
Risk of damage to the connecting cables during mounting.
Tensile loads and sharp edges can damage the strands and connecting cables of the male connector system.
Avoid tensile loads and look out for sharp edges when mounting the connector system.

4.4.1 Mounting in the cylinder

4.4.1.1 Insertion in the cylinder

1. Lubricate the O-ring, support ring and pressure pipe.



2. Carefully insert the encoder into the cylinder.
3. Guide the connecting cable carefully through the cylinder wall (bore hole).

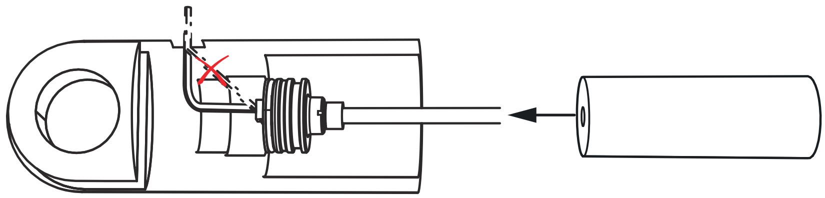


Figure 26: Tensile load at edges

NOTE

- Max. tensile force: 15 N (MAX48N)
- Max. tensile force: 15 N (MAX30N)
- Max. tensile force: 30 N (MAX48A)

4. Depending on the device variant, follow the steps below:
   - M12 male connector system:
   - Cable connection and cable gland:
5. Use a specially prepared sleeve (e.g., made from polyamide) to locate the device in its final position.
6. Carefully tap in the sleeve using a mallet.

DANGER

Risk of damage to the device during mounting.

Forces acting on the load-bearing features of the housing can damage the device.

Do not apply any load on the pressure pipe or behind the head of the device when mounting the sensor.

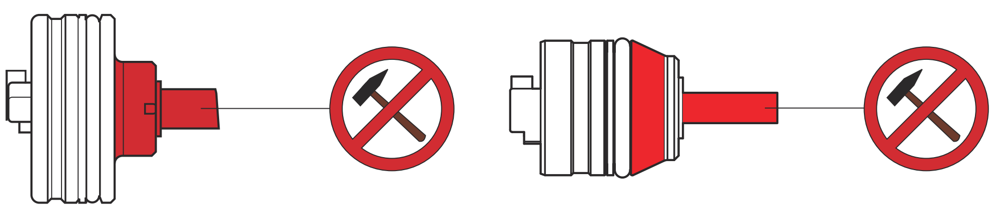
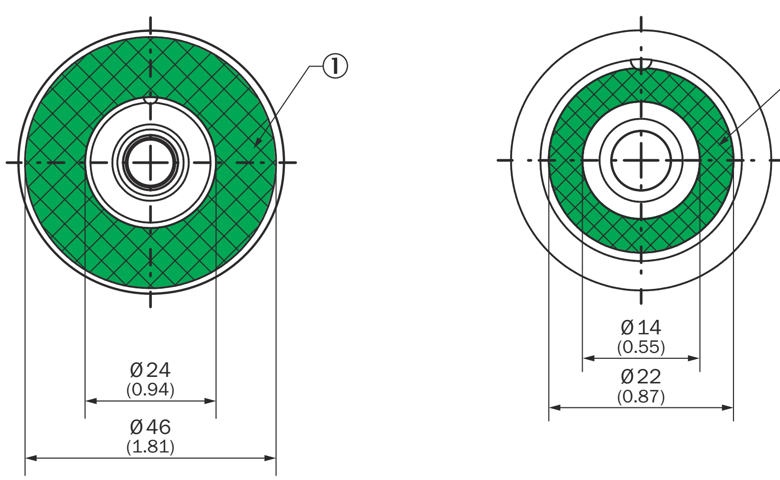


Figure 27: Damage during mounting

The surfaces marked with red may be mechanically loaded (left MAX48 and right MAX30)



Only the ring surfaces on the housing ① marked with green may be mechanically loaded with an axial force

4.4.1.2 Attaching retaining screws

The retaining screw prevents the housing from moving in the axial direction. A DIN913 M5x10 threaded pin with tapered head should be used for this purpose. Use a soluble screw locking adhesive when installing the threaded pin.

NOTICE
Risk of damage to the device during mounting.

The screw must only rest in the slot and not be tightened too hard.

- Tighten the screws with a torque of 0.5 Nm – 1.0 Nm.

4.4.2 Mounting M12 male connector system

The M12 male connector system with the strands is already ready to assemble.

NOTE
The M12 male connector system has enclosure rating IP69k. When selecting the mating connector, ensure that it also has an enclosure rating of IP69k.

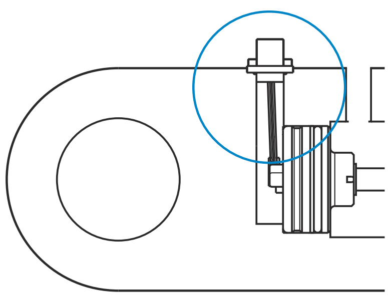


Figure 28: M12 male connector system

1. Mount and engage the contact carrier in the M12 mounting flange.

NOTICE

- When mounting the contact carrier in the flange, ensure the lug of the contact carrier is aligned correctly.

2. Press the mounting flange into the bore in the cylinder wall.
3. Fasten the mounting flange using suitable screws or rivets.
4. Follow the additional step: See document "Quickstart" 8021471 on the product pages of the MAX® www.sick.com/MAX®
5. Use a specially prepared sleeve (e.g., made from polyamide) to locate the device in its final position.

Recommended screws for mounting the M12 flange

The screws should be selected so that no collision with the coupling nuts of the connected mating connectors can occur, e.g.,:

- M3 or M4 socket head cap screw with flat head
- DIN912 hexagon socket screw
- ISO14580 multi-point screw
- DIN84 slotted screw
- Comparable Phillips head screws or self-tapping screws

A soluble screw locking adhesive should be used when installing the screws.

Alternatively, the flange plate can be fastened using DIN6660 button-head rivets.

4.4.3 Mounting cable gland

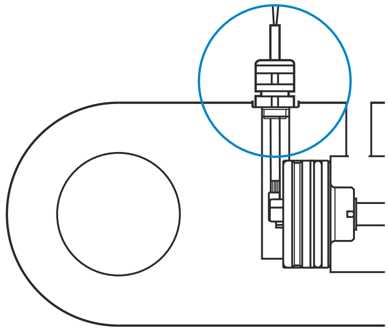


Figure 29: Encoder installed in the hydraulic cylinder with cable connection and cable gland

1. Guide the cable through the cable gland.
2. Mount the cable gland through the threaded bore.
3. Secure the tapered seal and coupling nut.
4. Follow the additional steps: See document "Quickstart" 8021471 on the product pages of the MAX® www.sick.com/MAX®
5. Use a specially prepared sleeve (e.g., made from polyamide) to locate the device in its final position.

NOTE
Observe the tightening torque of 4 Nm.

Recommendations regarding the cable gland

For devices with a cable connection, a protection class rated (preferably IP68) metallic cable gland should be used for sealing and strain relief. The cable glands should also be protected against damage by surrounding them with steel profiles (e.g. U-steel). A suitable cable gland is available as an accessory, product pages of the MAX® www.sick.com/MAX® or:

- MAX48N product information: 8021725
- MAX48A product information: 8025846
- MAX30N product information: 8025847

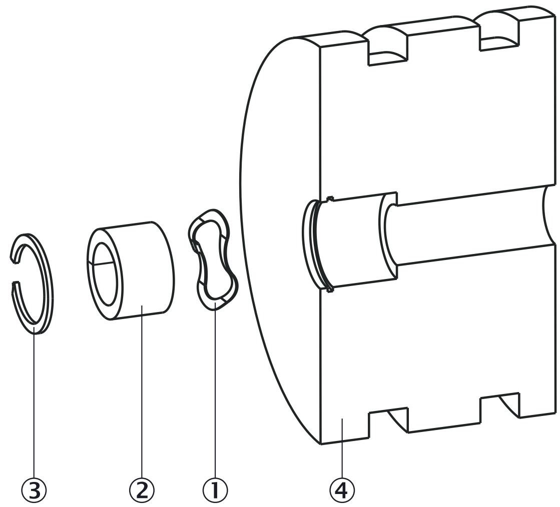
Recommendations regarding male device connectors for devices with a cable connection

When mounting male device connectors on devices with a cable connection, please consider the following:

- Enclosure rating: (preferably IP68)
- Male connector housing: metal or impact-resistant plastic (check media resistance)
- Protect against external influences: enclose the cable sheath and male connector
- Prevent fluid ingress: the cable sheath should ideally be coated with sealing compound at offset locations
- Polarity: ensure correct polarity
- Male connector with screw terminals: apply ferrules and clamp all strands in the ferrule
- Soldered connections: no projecting strands or "cold joints"
- Crimp contacts: use a suitable tool to produce a gas-tight crimp
- ESD protection: protect workplaces and persons from electrostatic discharge
- Prevent fluid ingress: use suitable caps to seal the male connector after mounting

4.5 Installation of position magnet

Recommended installation



①	Corrugated spring washer
②	Position magnet
③	Circlip
④	Piston

Table 7: Position magnet installation dimensions

① Corrugated spring washer	OD: 19.0 mm / 0.750 in ID: 15.0 mm / 0.500 in H (unloaded): 4.0 mm / 0.160 in see table 44
② Position magnet	17.4 x 12.0 x 10.6 mm see table 44
③ Circlip	OD: 19.0 mm / 0.750 in ID: 15.2 mm / 0.590 in H: 0.94 mm / 0.037 in DIN472-18x1, alternative see table 44
Diameter of the position magnet bore hole	17.5 + 0.1 mm
Depth of the position magnet bore hole	13.0 + 0.1 mm

NOTICE

Please observe the following information:

- Ensure that the circlip and the corrugated spring washer are made from non-magnetic material (non-ferritic steel).
- Ensure that the position magnet and the circlip do not rub against the pressure pipe.
- Smalley circlip (see table 44): does not contain any internal edges or eyes for the pressure pipe.
- Observe the operating pressures: see “Technical data”, see table 41.
- Consider bore hole depth in the piston and piston rod.
- Axial holding force of the position magnet is determined by the spring constant of the corrugated spring washer (approx. 15 N to 20 N) .
- No direct contact of the ring surface of the position magnet to the piston head.

Sequence of work steps:
1. Prepare the piston for installation of the magnet: see "Position magnet installation cavity" see figure 24, page 23.
2. Mount the corrugated spring washer.
3. Mount the position magnet.
4. Mount the circlip.

4.6 Cylinder design

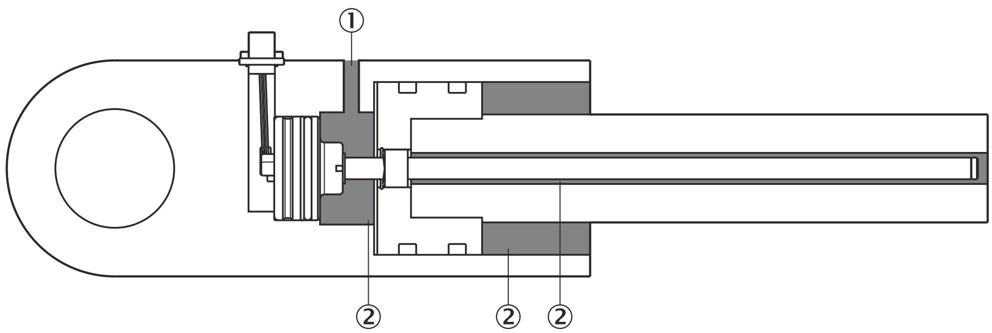


Figure 30: Areas requiring lubrication

① Hydraulic port

② Areas requiring lubrication

When bringing the piston rod and the piston together, make sure that the pressure pipe and the position magnet are not damaged. Lubricate the indicated areas via the oil inlet.

4.7 Cylinder handling after encoder installation

4.7.1 Washing and drying the cylinder

To protect the connecting cable and male device connector from ingress of cleaning agents, please observe the following:

Encoder with M12 male connector system

- Drying temperature: max. 90 °C
- Pressure of the cleaning fluid: ≤ 5 bar
- Use of a mounted metal protection cap

Preventing ingress of cleaning agents into the electronics when washing cylinders with an already installed M12 male connector.

To protect cylinders with an installed linear encoder against water ingress during washing, a brass cap (ideally with sealing insert) can be screwed onto the M12 male connector. Contact SICK for the relevant information.

Encoder with cable connection / installed male device connector

- Cable connectors / male device connector: protect against ingress of cleaning agents using suitable sheathing
- Cable glands: protect against ingress of moisture

4.7.2 Electrostatic painting of the cylinder

The electrostatic painting process uses very high voltages (up to 100 kV) which can damage the electronics of the encoder integrated into the cylinder. To avoid damage, observe the following when painting the cylinder:

- To avoid electrical isolation of the piston rod and the cylinder/sensor housing, do not the suspend the cylinder by the piston rod
- Clean off all lacquer and other residues from the hanging devices in the paint shop, all connectors used to short-circuit the connecting wires, and all connections to the paint shop earthing

Painting cylinders with an installed encoder and M12 male connector system

To protect the sensor electronics, use metal protective caps that meet the following requirements:

- The cap must not be made from aluminum
- The cap must be made from a permanently electrically-conductive material
- The cap must have an M12x1 thread
- The cap must be screwed on until it contacts the flange plate on the male connector
- Always use a torque of ≥ 5 Nm when tightening the cap
- Make sure no paint particles get onto the thread or pin contacts

Any paint particles on the outside of the cap will not impair the sensor.

Painting cylinders with an installed encoder and cable connection

Cylinders with an installed encoder and cable connection cannot be electrostatically painted because the cable connection cannot be protected against voltage. Reliable electrostatic painting is only possible when using a combination of M12 male connector system and protective cap.

5 Electrical installation

5.1 Electrical connection

The encoder is equipped with an M12 connector system.

A variant with a cable connection is also available. Male device connectors must be used in this case.

Enclosure ratings

To guarantee an IP69K enclosure rating (M12 connector system), a suitable mating connector must be used.

5.1.1 Connection diagram, pin assignment for 4-pin M12 male connector

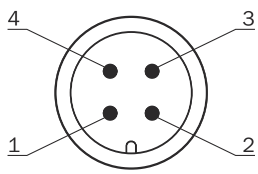


Figure 31: Pin assignment for 4-pin M12 connector

Pin assignment as per position 13 of the type code.

Table 8: Pin assignment for 4-pin M12 connector (color code acc. to 5.1.2)

Type code	A	B	M	E	G	H
12/24 VDC	1	1	2	2	1	1
GND (0 V)	3	3	3	3	3	3
Signal	4	2	4	4	4	2
n.c.	2	4	1	1	2	4

5.1.2 Connection diagram, pin assignment for 5-pin M12 male connector

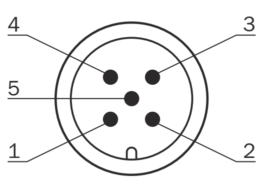


Figure 32: Pin assignment for 5-pin M12 connector

Pin assignment as per position 13 of the type code.

Table 9: Pin assignment and wire color for 5-pin M12

Type code	Wire color	C	D	F	S
12/24 VDC	BR (brown)	2	1	2	1
GND (0 V)	BL (blue)	3	3	3	3
CAN_HI	BK (black)	4	4	4	4
CAN_LO	WH (white)	5	5	5	5
n.c.		1	2	1	2

5.1.3 Connection diagram - cable or single strands

Connection scheme as per type code, position 13 = “K” (3-wire) or “T” (4-wire)

Table 10: Allocation of wire colors (voltage / PWM)

12/24 VDC	BR (brown)
GND (0 V)	BL (blue)
Voltage / PWM signal	BK (black)

Table 11: Allocation of wire colors (current)

12/24 VDC	BR (brown)
GND (0 V)	BL (blue)
Current signal	WH (white)

Table 12: Allocation of wire colors (CANopen/SAE J 1939):

12/24 VDC	BR (brown)
GND (0 V)	GND (0 V)
CAN_HI	BK (black)
CAN_LO	WH (white)

5.1.4 Connection sequence

Connect the wires in the following sequence:

1. Connect the 12/24 VDC voltage supply.
2. Connect the GND (0 V).
3. Connect the signal.

5.2 Connection diagram for vehicle electronics

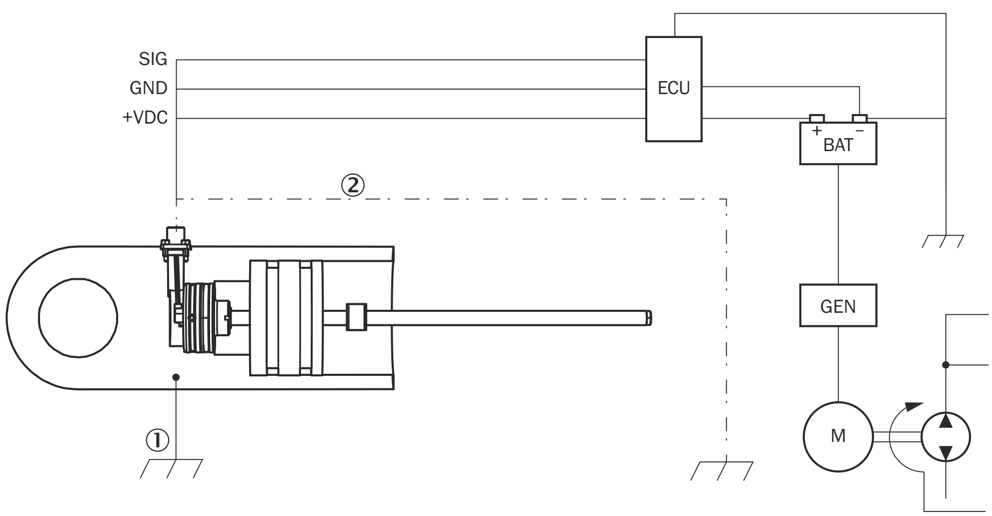


Figure 33: Connection diagram

① Chassis GND

② Cable shielding (optional)

To guarantee fault-free operation of the device, the cylinder must be connected to machine ground (Chassis GND).

The mechanical contact with another machine component equalizes the potential of the cylinder. If the cylinder is mounted in an insulated manner, separate earthing must be provided, e.g., by connecting a ground strap directly to the cylinder.

Cable shielding

The encoder is adequately shielded by the cylinder when installed, and the 3-wire connecting cable has not been provided with its own shielding. If a shielded cable with M12 mating plug is used, e.g. in a CANopen network, it is necessary to check (depending on the application) whether one side or both sides of the shield should be connected to machine ground. Any high voltage or high frequency fields in the vicinity can influence the shielding and the signals.

Operation according to EMC requirements in accordance with EN 61000-6-2/3

With the condition that the connecting cable is < 30 m, no surge voltage tests are required according to EN 61000-6-2 in chapter 3.5 and table 2. The direct current supply input is considered a signal connection.

Mounting the encoder housing outside the cylinder

For housings with screw-in studs or flange housings, care must be taken to ensure the correct ground connection to chassis GND and the required shielding.

6 Commissioning

6.1 Tolerance considerations for the set point

The set points (zero/end point) of the device are adjusted to a tolerance of ± 1 mm.

NOTICE
Further tolerances must be observed when installing the cylinder.

During teach-in, the piston rod moves to the zero point and to the end point in order to eliminate all tolerances in the cylinder/encoder combination. The measured signals are programmed in the controller accordingly. When operating the device without teach-in, please note the following tolerance-related information:

Table 13: Tolerances when operating the device without teach-in

Example for a measuring range of 400 mm				
	Analog VDC	Analog mA	PWM (duty cycle)	CANopen SAE J1939
Signal	0.5 … 4.5 V	4 … 20 mA	10 … 90%	PDO
Range	4000 mV	16 mA	80%	4,000 digits
Zero/end point ± 1.0 mm	± 10 mV	± 0.04 mA	± 0.2%	± 10 digits
Position magnet ± 1.0 mm	± 10 mV	± 0.04 mA	± 0.2%	± 10 digits
Mechanical assembly ± 0.5 mm	± 5 mV	± 0.02 mA	± 0.1%	± 5 digits
Total of all tolerances ± 2.5 mm	± 25 mV	± 0.10 mA	± 0.5%	± 25 digits

Table 14: Zero end point

Example for a measuring range of 400 mm				
Output	Analog VDC	Analog mA	PWM (duty cycle)	CANopen SAE J1939
Signal	0.5 … 4.50 V	4 … 20 mA	10 … 90%	PDO value
Zero point	± 25 mV	± 0.10 mA	± 0.5%	± 25 digits
min. zero point	0.475 V	3.90 mA	9.5%	275 digits
max. zero point	0.525 V	4.10 mA	10.5%	325 digits
End point (F.S.)	± 25 mV	± 0.10 mA	± 0.5%	± 25 digits
min. end point	4.475 V	19.90 mA	89.5%	3,975 digits
max. end point	4.525 V	20.10 mA	90.5%	4,025 digits

After installation of the encoder in the cylinder, deviations from the target values will arise due to these permissible tolerances. These deviations must be taken into consideration when setting limit values in the controller:

Table 15: Deviation from the limit values

Typical values			
	Cylinder stroke (mm)		
	200 mm	400 mm	800 mm
Output signal	Tolerances		
Analog V DC	± 50 mV	± 25 mV	± 12.5 mV
Analog mA	± 0.20 mA	± 0.10 mA	± 0.05 mA
PWM (10 … 90% duty cycle)	± 1.0%	± 0.5%	± 0.25%
CANopen / SAE J1939	± 25 digits	± 25 digits	± 25 digits

6.2 Putting the encoder into operation

1. Check that the connectors have been connected correctly: see "Connection diagram, pin assignment for 4-pin M12 male connector", page 31.
2. Select a suitable fuse: see "Select a suitable fuse", page 35.
3. Set up the filter wiring: see "Set up the filter wiring - analog", page 35.
4. Put the device into operation.
5. Check the functioning of the encoder: see "Checking the functioning of the encoder", page 44.

6.3 Select a suitable fuse

When selecting a suitable fuse, the transient peak current when switching on the device for the time must be taken into consideration:

Table 16: Inrush current when switching the device on

Inrush current for an supply voltage of 12 VDC	2.5 A / 50 µsec typical
Inrush current for an supply voltage of 24 VDC	5.0 A / 50 µsec typical

6.4 Set up the filter wiring - analog

Thermal noise, for example from resistors, becomes evident when the signal output is amplified sufficiently. The supply voltage ripple (see "Technical data", page 48) and other sources of interference, e.g., electromagnetic interference, can also affect the quality of the analog output signal. To reduce the noise when acquiring analog measurement data, it is essential to use a filter.

A suitable filter, for example, is a combination of R1 = 50 Ω and C1 = 100 nF to 1 µF. This will keep the signal delay time within the cycle time (internal measurement frequency) while not changing the dynamic behavior significantly.

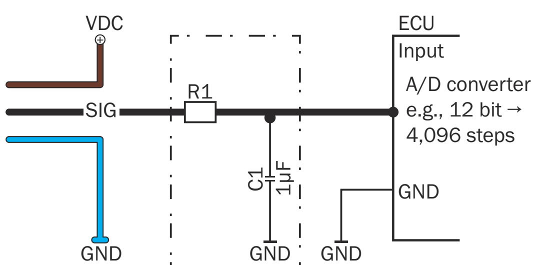


Figure 34: Filter wiring

NOTICE
The A/D converter at the input of the installed electrical controller will determine the resolution of the encoder, e.g.,:

- 8 bit = 256 steps
- 10 bit = 1,024 steps
- 12 bit = 4,096 steps

6.5 Power-up and output signal in the event of a fault

When switching on the device, the signal output is ≥ F.S.O = Full Scale Output. After that the device is ready for use.

Table 17: Operational statuses and output signal

Output signal		
F.S.O	during power-up	in the event of a fault

Output signal		
4.00 ... 20.00 mA	Unusable signal	> 21.0 mA
0.50 ... 4.50 V		> 5.1 V
0.25 ... 4.50 V		> 5.1 V
0.50 ... 9.50 V		> 10.0 V
PWM (duty cycle)		≥ 99%
Digital: CANopen / SAE J1939	Boot message	Error message “FFFF”

Fault:

a) Position magnet missing
b) Position magnet in null or cushion zone
c) Malfunction or failure of the magnetostrictive element

During the power-up delay (see "Technical data", page 48), the output signal is defined as an unusable signal. The machine controller must take this into consideration in its processing. After the power-up delay, the linear encoder is ready for operation. The output signal behaves as described in the event of a fault.

6.6 Bus termination - digital

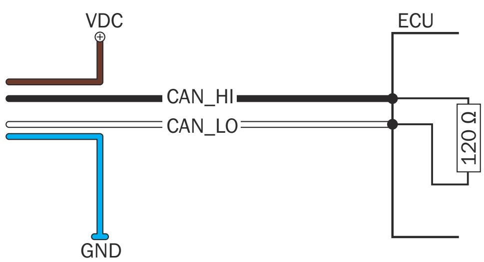


Figure 35: Bus termination

Data transmission in the CAN bus is serial (2-wire bus system). The voltage difference between the CAN_HI and CAN_LO data lines is one bit of information. To prevent signal reflections, the data lines must be terminated with a 120 Ω terminator on the open bus end. The terminator must be inserted between CAN_HI and CAN_LO.

6.7 CAN bus protocols

CAN bus is a machine level, open field bus for serial data transmission between a central controller (master) and decentralized field devices (slaves). Various protocols can be used for the data transmission depending on the application. The device can be ordered with either CANopen or SAE J1939 protocol support. Each protocol is configured differently, which affects how the device is integrated into the network, and the operating characteristics of the device.

CANopen

The CANopen version of the device is suitable for operation as a slave in CAN bus networks using the CiA Standard DS 301 data protocol. This protocol corresponds to the DS 406 encoder profile. The device is connected directly to the bus as a node of the bus system. The device distinguishes between four different operational statuses initiated by the controller. These statuses are defined in the CANopen standard:

- Initialization: The device performs a hardware initialization and loads the most recently saved standard configuration.
- Pre-operational: The device can be configured via the CAN bus.

- Operational: The device sends its measurement data via the CAN bus.
- Stopped: The device stops transmitting data and waits for further commands.

SAE J1939

SAE J1939 is a multi-master protocol developed especially for applications in the mobile field, i.e. for commercial and conveyor vehicles, as well as for construction, agricultural and forestry machines. An SAE J1939 network consists of various ECUs (Electronic Control Units). An ECU can address messages to multiple CAs (Controller Applications). After commissioning, the bus subscribers are automatically assigned addresses. The CAN bus subscribers are now fully operable.

6.8 Communication objects

6.8.1 CANopen

When the device is in operational mode, the evaluation electronics integrated into the device convert the measurement data into CAN messages, and transmit these messages on the CAN bus. Where they can be received and processed by the controller. The CAN bus uses the following communication objects for data transmission:

- SDO (Service Data Object):
  SDOs are used to set or query parameters relating to the encoder configuration. These are accessed from the internal object directory of the device. To process SDOs, the device must be in either the pre-operational or operational mode.
- PDO (Process Data Object):
  PDOs transmit process data, such as position and speed, to the controller. PDOs are only generated in operational mode.
- NMT (Network Management):
  NMTs control the status of the network and individual components. They can also be used for monitoring purposes using the following objects:
  - SYNC object:
    The SYNC object synchronizes the bus communication, i.e. synchronous PDOs are sent to the controller after a SYNC object is received.
  - Emergency object:
    The emergency object sends error messages. As they generally have a higher priority than PDOs, these emergency objects will be transmitted first.
  - Nodeguard object:
    The CANopen linear encoder uses the node guarding protocol to perform the error control services of the CANopen network.
    The bus master uses a remote frame to send a nodeguard message to the CANopen slave, and in response the slave reports its current NMT status using a standard nodeguard message. The nodeguard frame format, and the NMT state value definitions are shown in the following tables. The nodeguard protocol is activated as default.

According to the CANopen protocol, each message has the following structure:

Table 18: Message in CANopen

SOF	Arbitration		Control	Data Field	CRC	ACK			EOF	Interframe Space
1	11	1	6	0..8 bytes	15	1	1	1	7	≥ 3

6.8.2 SAE J1939

SAE J1939 features an extended message arbitration and a 29-bit extended message identifier. This extension features a different message prioritization and assignment of bus subscribers. For large quantities of data, it is possible to utilize a separate transport protocol. The communication objects for SAE J1939 are:

- PDU (Protocol Data Unit):
  There are two types of PDUs. PDU1 is used for peer-to-peer data transmission, PDU2 is addressed to all bus subscribers.
- PG (Parameter Groups):
  PG refers to the grouping of process data and parameters for transmission in a message. This parameter group data structure ensures efficient bus loading.
- PGN (Parameter Group Number):
  The PGN is a unique and standardized identifier of the parameter group.
- SPN (Suspect Parameter Number):
  The SPN uniquely identifies a parameter signal and is prescribed by the protocol. This ensures that every SAE J1939 compatible device knows the parameter structure.
- TP (Transport Protocol):
  TP is used for separate data transmission above 8 bytes.

According to the SAE J1939 protocol, each message has the following structure:

Table 19: CAN bus data protocol with J1939 identifier

PDU												
SOF	Arbitration Identifier					Control	Data Field	CRC	ACK			EOF
1	Priority 3	2	PDU Format 8	PDU Specific 8	Source 8	6	0..8 bytes	15	1	1	1	7

6.9 Configuration and system startup

After electrical connection to the network, the device is ready for commissioning and configuration. Before actual system startup, the communication parameters for operation need to be set in the CAN bus. Only the basic procedure is described in these operating instructions. Please refer to the “Technical information (8022392)” for details on all the available commands for configuring the device.

6.9.1 Configuring CANopen

Setting the node parameters

To be able to operate the device in a CAN bus network, it is necessary to first configure the network characteristics. The basic settings for integrating a bus subscriber are made using LSS (Layer Setting Services). Every device (node) in the CAN network is uniquely identified by its LSS address. This address is composed as follows:

Table 20: LSS address

	CANopen
Vendor-ID	1000056h
Product code	as per product key
Revision number	as per product key
Serial Number	actual serial number of the CANopen encoder

Parameters specific to the CAN bus, such as baud rate and node ID, are also configured and saved via the LSS service. Both the baud rate and node ID of the encoder must be configured for operation in the specific CAN bus implementation.

Setting the node ID

NOTE
When programming the node ID, only one device or node must be connected.

Every device or node must be assigned a number (node ID). This number is used to identify the node within the CANopen network. Each node ID must be unique. The CANopen node ID must be in the range of 1 - 127, and can be preset when ordering the encoder (using the type code). To ensure error-free operation of the network, the ID of every node in the CAN bus must be unique.

The node ID of the device can be set using the following command sequence:

Table 21: Setting the node ID

Data source	COB-ID	Data	Destination
Controller	7e5h	04; 01; 00; 00; 00; 00; 00; 00	Sensor
Controller	7e5h	11; 7d*; 00; 00; 00; 00; 00; 00	Sensor
Sensor	7e4h	11; 00; 00; 00; 00; 00; 00; 00	Controller

* Node address values can be between 1 and 127 (for example 125).

A change in node address is effective immediately.

To permanently save the node address, the following command must be sent:

Table 22: Saving the node ID

Data source	COB-ID	Data	Destination
Controller	7e5h	17	Sensor
Sensor	7e4h	17; 00; 00; 00; 00; 00; 00; 00	Controller

Setting the baud rate

The baud rate indicates the speed of operation of the device and also the entire CAN bus. The device and entire network must be set to the same baud rate.

The maximum baud rate is limited by the cable length used for the CAN network as a whole. The device is delivered with a preset, order-dependent baud rate. If this baud rate needs to be changed, it can be configured via the LSS.

Table 23: Baud rate as a function of cable length

Cable length	Baud rate (kBit/s)	Table index
< 25 m	1000	00
< 50 m	800	01
< 100 m	500	02
< 250 m	250	03
< 500 m	125	04
< 1000 m	50	06
< 2500 m	20	07
< 5000 m	10	08

The baud rate can be set using the following commands:

Table 24: Setting the baud rate

Data source	COB-ID	Data	Destination
Controller	7e5h	04; 01; 00; 00; 00; 00; 00; 00	Sensor
Controller	7e5h	13; 00; 02*; 00; 00; 00; 00; 00	Sensor
Sensor	7e4h	13; 00; 00; 00; 00; 00; 00; 00	Controller

* Table index

The baud rate becomes active after saving the changes, and the next time the encoder is switched on. To save the baud rate, the following command must be sent:

Table 25: Saving the baud rate

Data source	COB-ID	Data	Destination
Controller	7e5h	17; 00; 00; 00; 00; 00; 00; 00	Sensor
Sensor	7e4h	17; 00; 00; 00; 00; 00; 00; 00	Controller

6.9.2 Configuring SAE J1939

In the SAE J1939 specification, the maximum length of the network is limited to 40 meters, and the baud rate is fixed at 250 kBit/sec. It is therefore not necessary to configure these parameters when integrating the device. Furthermore, the number of nodes is limited to 30 ECUs (Electronic Control Units). Each ECU can, however, control multiple CAs (Controller Applications). Up to 253 CAs in total can be implemented in the network.

NMT (Network Management)

The naming conventions are defined in SAE J1939 and are structured as follows:

Table 26: Naming structure for subscribers according to J1939

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
Identify Number		Manufacturer Code		ECU Instance	Function

Table 27: Naming structure for subscribers according to J1939

Byte 6		Byte 7		
Reserved	Vehicle System	Vehicle System Instance	Industry Group	Arbitrary Address Capable

Table 28: Setting the source address

Data source	COB-ID	Data	Destination
Controller	10ff54d4h	01; nSA*; 23; 01; 20; 07; 00; 00	Transducer
Transducer		No response	Controller

* nSA: new source address

6.9.3 System startup for CANopen

After configuring the node parameters, the device can be integrated into the network. When switched on or reset, the encoder performs a hardware initialization to bring all components into a defined initial state. Next the device- and communication-specific parameters are loaded from an EEPROM and the configuration adopted.

Once the initialization has been completed, the device reports its node ID and **pre-operational** mode to the network master by means of a boot-up message. While in this mode, the device can be configured via service data objects (SDOs).

The SDO identifiers are generated automatically based on the node ID. The communication via SDOs to configure the device takes the form of a peer-to-peer connection between the network master and the device. The identifiers for the other objects are also allocated according to the CANopen standard. They can, however, be changed at any time in the CANopen network via a DBT master. If necessary, the changed parameters can be saved in the EEPROM and loaded automatically the next time the device is switched on and configured.

Once the configuration process is finished, the encoder is switched from **pre-operational** to **operational** mode using a Start_Remote_Node command. While in this mode, user data can be transmitted (via PDOs). The transmission of the PDOs can occur in one of two ways:

Either the encoder sends its data cyclically, or data transmission is triggered by the receipt of a SYNC object.

To initiate the sending of position messages by the encoder, it is necessary to first send a node start message:

Table 29: Node start message

Data source	COB-ID	Data	Destination
Controller	000h	01; 00*; 00; 00; 00; 00; 00; 00	Sensor

* 00: Starts all CAN nodes

To stop the sending of position data, it is necessary to send a pre-operational message:

Table 30: Pre-operational message

Data source	COB-ID	Data	Destination
Controller	000h	80; 00*; 00; 00; 00; 00; 00; 00	Sensor

* 00: Sets all nodes to **pre-operational** mode

6.9.4 System startup for SAE J1939

After the device is connected to the network and switched on, it attempts to register itself with the network master using a source address. This address claiming is performed automatically by the network. After assignment of a unique network address, the device starts sending position data and is also ready to receive configuration data.

6.9.5 Setting CANopen operating parameters

At system startup (power on, reset), the device loads the operating parameters stored in the EEPROM. These are either the factor-set values, or previously changed and saved values.

Changes are made, for example, via SDOs while in **pre-operational** mode. The identifiers are automatically set to suitable default values and saved when programming the node ID. They can subsequently be changed.

These operating parameters are stored in the object directory of the device, which provides the means for implementing the internal characteristics and functions of the device, as well as external communication. For this purpose, the object directory is divided into two parts: a Communication Profile, and a Device Profile.

- **Communication Profile:**
  The Communication Profile contains the parameters relevant to communication, e.g., identifier settings and PDO configuration settings. The device is equipped with the encoder communication protocol (Device Profile for Encoder – DS406 Vers. 3.1). This enables devices from different manufacturers to be easily linked to one another and replaced.
- **PDO transmission type:**
  By default, the PDO transmission type is set to asynchronous, i.e. the encoder transmits its process data independently according to the configured cycle time. The PDO transmission type can also be set in such a way that process data is only sent after a SYNC message is received.
- **PDO object mapping:**
  The device does not support dynamic mapping or changing of the mapping parameters. PDO1 transmits the position and speed.
- **Error messages:**
  The device automatically sends an emergency object when an error arises.
- **Device Profile:**

The parameters important to the operation of the encoder, such as position resolution, speed resolution, and cycle time, are stored in the Device Profile. Two important operating parameters are:

- **Resolution:**
  The factory-default resolution of the device is 100 µm. The resolution for motion speed is set to 1 mm/s by default. For more information, see the programming instructions.
- **Cycle time:**
  This setting is the cycle time for transmission of PDOs. The value can be in the range of 1 ... 65,535 ms. Programming the cycle time (object 6,200) only affects the PDO1 event timer (see DS406 V3.0).
  The cycle time setting must match the setting configured for the CAN bus network. If the cycle time is too short, and the baud rate is low and there are many subscribers, the bus can become overloaded due to the increased volume of data.
  The cycle time can be set using the following commands (e.g., 10, node ID = 127*):

Table 31: Setting the cycle time

Data source	COB-ID	Data	Destination
Controller	67fh*	22; 00; 62; 00; 0A; 00; 00; 00	Sensor
Sensor	5ffh*	60; 00; 62; 00; 00; 00; 00; 00	Controller

To permanently save the cycle time, the Save parameters command must be executed:

Table 32: Saving the cycle time

Data source	COB-ID	Data	Destination
Controller	67fh*	22; 10; 10; 01; 73; 61; 76; 65	Sensor
Sensor	7ffh*	60; 10; 10; 01; 00; 00; 00; 00	Controller

NOTE
The encoder may take up to 600 ms to respond.

6.9.6 Setting SAE J1939 operating parameters

The operating parameters of the SAE J1939 device variant can be set analogously to the CANopen variant. The device can receive configuration messages during operation, and will adopt the settings immediately after receiving the message.

The cycle time can be set using the following commands (e.g., 100*):

Table 33: Setting the cycle time

Data source	COB-ID	Data	Destination
Controller	18B2SAMAh	4D; 54; 53; 00; 64*; 00*; 00; 00	Sensor

SA MAX® CAN J1939 Standard Sensor Source Address
MA Master source address
* e.g., 64; 00: Bytes to configure transmission repetition rates

6.9.7 CANopen encoder data during operation

Data is outputted by means of a Process Data Object (PDO). The PDO contains the position and speed data.

Data format

The resolution of the position data is fixed at 100 µm, and the resolution of the speed data is 1 mm/s. The currently set values can be read under index 6005 of the object directory. All position data are stored as 32-bit integer values, and speed data as 16-bit integer values.

Table 34: PDO allocation when using the default settings

Identifier	DLC	D0	D1	D2	D3	D4	D5
180h + node ID	6	Position magnet 1				Speed magnet 1	

The position and speed are calculated as follows:

Position [µm] = position value [counts] * 100µm

Speed [mm/s] = speed value [counts] * 1 mm/s

6.9.8 SAE J1939 encoder data during operation

Data is outputted by means of a Data Record Message.

Table 35: Data Record Message

Identifier	DLC	D0	D1	D2	D3	D4	D5	D6	D7
0 x 18 PFPSSA	8	Position		Speed		Status	Error Code	Limit Status	0xFF

PF PDU format is fixed to 255 (0xFF)
PS PDU Specific can be 0-255 (0x00 - 0xFF)
SA MAX® CAN J1939 Standard Sensor Source Address

6.9.9 CANopen error messages

An emergency object is sent whenever there is a change to the internal error status register (even if the error has since been rectified). The object comprises 8 data bytes and is structured as follows:

Table 36: Emergency object

Identifier	DLC	D0	D1	D2	D3	D4	D5	D6	D7
0x80 + node ID	8	Error Code		Error register	Manufacturer-specific				

The following errors are reported in the emergency object:

Table 37: Error codes

Error code	Relevance
0000 h	Device is operating without errors
5,000 h	Device hardware error
6,300 h	Data set error

6.9.10 SAE J1939 error messages

SAE J1939 does not provide separate error objects. The device status is reported with every PDU that is sent.

7 Maintenance

7.1 Error table

Table 38: Errors during installation

Error cause	Possible consequences
Incorrect pin assignment	No signals
Ambient temperature too high	Damage to the device components
Cylinder bore hole too small	Damage to the device components when installing the device
Not noticing pointy or sharp edges	Damage to male connectors, wires, cables
Careless handling of the device	Damage to the device components
Welding work after installation	Damage to the sensor housing or electronics due to welding currents
Damage to the cable	Short-circuiting or failure of the electronics
Male connector not sealed	Short-circuiting or corrosion of electronic components due to liquids
Ground or shielding connected incorrectly	Signal interference, possible damage to the electronics

Table 39: Errors during commissioning/operation

Output signal	
F.S.O	Output signal in the event of a fault
4.00 ... 20.00 mA	> 21.0 mA
0.50 ... 4.50 V	> 5.1 V
0.25 ... 4.50 V	> 5.1 V
0.50 ... 9.50 V	> 10.0 V
PWM (duty cycle)	> 99%
Digital: CANopen / SAE J1939	Error message “FFFF”

Fault:

a) Position magnet missing
b) Position magnet in null or cushion zone
c) Malfunction or failure of the magnetostrictive element

7.2 Checking the functioning of the encoder

Encoder with analog interface

To verify the proper operation of the device, perform the following checks:

- Connections and pin assignments
- Supply voltage
- Check the device by disconnecting it and testing it using an external supply
- Check the device using a multimeter as described below

Measure the VDC output signal

Measure the following output signals:

- 0.25 ... 4.75 V
- 0.5 ... 4.5 V
- 0.5 ... 9.5 V
- 9.50 ... 0.50 V

- 9.00 ... 1.00 V
- 4.75 ... 0.25 V

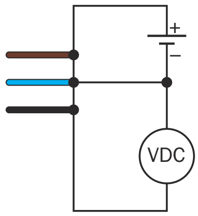


Figure 36: Measuring the output signal in VDC

1. Switch the measuring range of the multimeter to VDC.
2. Connect the multimeter to the signal lead and 0 V lead.
3. Connect the voltage supply (+12/24 V).
4. Connect 0 V (-0 V).

Measuring output signals 4 ... 20 mA / 20.00 ... 4.00 mA

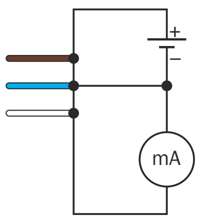


Figure 37: Measuring the output signal in mA

1. Switch the measuring range of the multimeter to mA.
2. Connect the multimeter to the signal lead and 0 V lead.
3. Connect the voltage supply (+12/24 V).
4. Connect 0 V (-0 V).

Alternative measuring method: using a resistor (e. g., 100 Ω):

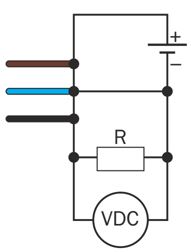


Figure 38: Measuring the output signal using a resistor

1. Connect the resistor to the signal lead and 0 V lead.
2. Switch the measuring range of the multimeter to VDC.
3. Connect the multimeter in parallel to the resistor.

When using a resistor of, for example, 100 Ω, the following values are displayed:

Table 40: Example measurement values

Supply	at 4 mA (null zone)	at 20 mA (end position)
12 V, 24 V	0.4 V	2 V

7.3 Repairs

All repair work on the device must be carried out by SICK Service.

8 Transport and storage

8.1 Transport and storage conditions

When transporting the fully assembled cylinders, ensure the cable and male connector of the electrical connection are not subjected to tensile loads.

Store the cylinders in a dry place. When storing the cylinders on top of one another, ensure no male connectors or cables are crushed.

Cover the connectors and any free cable ends with an anti-static bag. The original packaging, for example, is suitable for this purpose. Also reuse the dust protection caps of the connector system when storing the device.

For the part numbers of the original packaging and the dust protection caps, see: see "Accessories", page 57.

9 Decommissioning

9.1 Dismantling

When dismantling the cylinder and when removing the encoder, ensure no male connectors, cables or cable ends can be damaged in the process.

9.2 Disposal

Any device which can no longer be used must be disposed of in an environmentally friendly manner in accordance with the applicable country-specific waste disposal regulations. As the device is categorized as electronic waste, it must never be disposed of with household waste.

10 Technical data

10.1 MAX® Analog / PWM

For details of applied tests and descriptive standards, please see document 8021472.

Table 41: Technical data - MAX® Analog / PWM

Performance	
Measurand	Position
Measuring range	
Position (F.S.[2])	MAX48N/MAX48A: 0050 ... 2,500 mm (in 1 mm increments) MAX30N: 0050 ... 1,500 mm (in 1 mm steps)
Unusable range	
Null zone (zero point)	MAX48N/MAX48A: 30.0 mm MAX30N: 21.5 mm
Damping zone (end point)	30.0 mm/ 36.0 mm/ 63.0 mm (depending on type)
Power-up delay	< 250 ms
Measuring frequency (internal)	2 ms
Setpoint tolerance	
Zero point and F.S. [2]	≤ 1.0 mm
Resolution	0.1 mm typical (noise-free)
Hysteresis	± 0.1 mm
Repeatability	Typ. ± 0.2 mm
Linearity (in operational status)	Typ. ± 0.25 mm (measuring range from 50 to 500 mm) Typ. ± 0.04% F.S. (Measuring range from 500 to 2,500 mm)
Temperature drift	
Self-heating of the electronics (warm-up phase)	Typ. ≤ ± 0.25 mm (2 min)
Operational status (hydraulic oil at operating temperature)	≤ ± 0.005% x F.S. x ΔT (ΔT 40 °C) [3]
MTTFd	69 years (EN ISO 13849-1) [4] [5]

Interfaces	**Analog**	**PWM**
Communication interface detailed	Voltage / current	PWM
Voltage output	0.25 ... 4.75 V 0.50 ... 4.50 V 0.50 ... 9.50 V 1.00 ... 9.00 V 9.50 ... 0.50 V 9.00 ... 1.00 V 4.75 ... 0.25 V 4.50 ... 0.50 V	-
Current output	4.00 ... 20.00 mA 20.00 ... 4.00 mA	-

2) F.S. = Full scale (measuring range end value)
3) Rise in oil temperature by 40 °C during operation
4) 69 years (EN ISO 13849-1)
5) Every 2nd failure of an electronic component is considered hazardous.

Interfaces	Analog	PWM
Pulse width	-	05% ... 95% 10% ... 95% 15% ... 85% 20% ... 80% 25% ... 75%
Frequency	-	250 Hz 300 Hz 400 Hz 500 Hz

Electrical data	Analog	PWM
Connection type	M12 male connector, 4-pin 3-wire connecting cable	
Supply voltage		
12 V DC	8 ... 16 V DC [6]	-
24 V DC	8 ... 36 V DC [7]	8 ... 36 V DC [7]
Residual ripple	< 1% p-p	
Power consumption		
12 V DC	≤ 0.75 W [6]	-
24 V DC	≤ 1.25 W [8]	-
24 V DC	≤ 0.75 W	
Current consumption		
12 V DC	≤ 60 mA [6]	-
24 V DC	≤ 50 mA [8]	-
24 V DC	≤ 30 mA	
Load resistance		
Voltage output	RL ≥ 10 kΩ	-
Current output	100 Ω ≤ RL ≤ 500 Ω	-
Inrush current		
12 V DC	Typ. 2.5 A / 50 µs	-
+24 V DC	Typ. 5.0 A / 50 µs	
Overvoltage protection		
12 V DC	≤ 18 V at all poles during power-up (60 s) ≤ 24 V to GND during power-up (60 s)	
+24 V DC	≤ 36 V at all poles during power-up (60 s) ≤ 48 V to GND during power-up (60 s)	
Reverse polarity protection	≤ 36 V (at all poles) (ISO 16750-2)	
Insulation resistance	R_{iso} ≥ 10 MΩ, 60 s (ISO 16750-2)	
Dielectric strength	500 V DC (0 V to housing) (ISO 16750-2)	

Mechanical data	
Dimensions	
Size	MAX48: 48f7 mm (for installation in a 48H8 bore hole) MAX30: 31f7 mm (for installation in a 31H8 bore hole)

6) Valid for voltage outputs 0.50 ... 4.50 V; 4.50 ... 0.50 V; 0.25 ... 4.75 V; 4.75 ... 0.25 V
7) 36 V only during power-up
8) Applies for current output 4 ... 20 mA; 20 ... 4 mA

Mechanical data	
ØPressure pipe	MAX48N/MAX48A: 10 mm MAX30N: 7 mm
ØO-ring	MAX48N/MAX48A: Ø 40.87 x 3.53 mm MAX30N: Ø 24.99 x 3.53 mm
ØSupport ring	MAX48N/MAX48A: Ø 48 x 42.6 x 1.4 mm MAX30N: Ø 31 x 25.8 x 1.4 mm
M12 flange type S	Construction DM 20x20 mm - hole pattern 14 mm (EN 61076-2-101)
M12 flange type L	Construction DM 24x24 mm - hole pattern 17 mm (EN 61076-2-101)
M12 male connector (strands)	60 ... 240 mm (depending on type)
Connecting cable / stripped strands	Ø5.0 mm / Ø 1.4 mm 300 ... 10.000 mm (depending on type) 3 x 0.38 mm^2 (AWG22)
Material	
Electronics housing	Stainless steel 1.4305, AISI 303
Pressure pipe	Stainless steel 1.4404, AISI 316L
O-ring	NBR 70
Support ring	PTFE
M12 plug insert	Glass fiber reinforced polyamide, nickel-/gold-plated brass contacts
M12 flange	Nickel-plated brass with O-ring (NBR)
Connecting cable / strands	PUR / PVC

Ambient data	
EMC	EU Directive 2014/30 / EU CE marking
Generic standards	MAX48N/MAX48A: EN 6100-6-2:2005 and EN 61000-6-3:2007 MAX30N: n.a.
Agricultural and forestry machinery, construction machinery	EN ISO 14982:2009 EN 13309:2010 / EN ISO 13766-1:2018
Transient pulses	ISO 7637-2
ESD (air and contact discharge)	EN 61000-4-2, ISO/TR 10605
Enclosure rating	
Housing	IP67 (EN 60529)
Housing with connecting cable / strands	IP67 (EN 60529)
M12 male connector	IP69k (ISO 20653) [9)]
Temperature	
Operating temperature range (electronics)	–40 °C ... +105 °C [10)]
Ambient temperature (fluid)	–30 °C ... +95 °C [11)]
Storage temperature range	–20 °C ... +65 °C [12)13)]
Permissible relative humidity	90% (condensation not permitted)
Resistance to shocks	Drop test according to IEC 60068-2-31 100 g, 11 ms (single shock in accordance with IEC 60068-2-27) 50 g, 11 ms (continuous shocks, 1,000 shocks per spatial axis in acc. with IEC 60068-2-27)

9) With suitable coupling (sealing through O-ring in coupling nut).
10) Taking into account self-heating generated through constant electrical operation with supply voltage.
11) Caused by the permitted temperature range of the O-ring seal, the hydraulic oil and the temperature-dependent signal quality of the position magnet.
12) Relative humidity 55%
13) Caused by dry storage of the O-ring in uninstalled state (no coating with oil).

Ambient data	
Resistance to vibrations	
Sine	MAX48N/MAX48A: 20 g, 24 h / spatial axis, 55 ... 2,000 Hz (IEC 60068-2-6) MAX30N: 15 g, 24 h / spatial axis, 55 ... 2,000 Hz (IEC 60068-2-6)
Sine-on-random	MAX48N/MAX48A:18 g (r.m.s), 36 h / spatial axis, 10 ... 2,000 Hz (IEC 60068-2-80) MAX30N: 13 g (r.m.s), 36 h / spatial axis, 10 ... 2,000 Hz (IEC 60068-2-80)
Noise (resonance peaks removed)	MAX48N/MAX48A: 20 g (r.m.s), 48 h / spatial axis, 10 ... 2,000 Hz (IEC 60068-2-64) MAX30N: 15 g (r.m.s), 48 h / spatial axis, 10 ... 2,000 Hz (IEC 60068-2-64)
Nominal operating pressure (PN)	MAX48N/MAX48A: 400 bar MAX30N: 320 bar
Max. overload pressure during operation (PN x 1.2)	MAX48N/MAX48A: 480 bar MAX30N: 380 bar
Max. test pressure in cylinder (PN x 1.5)	MAX48N/MAX48A: 600 bar MAX30N: 480 bar

10.2 MAX® Digital CANopen / SAE J1939

Table 42: Technical data – MAX® Digital CANopen / SAE J1939

Performance	
Measurand	Position and speed
Measuring range	
Speed	0 ... 1,000 mm/s
Unusable range	
Null zone (zero point)	MAX48: 30.0 mm MAX30: 21.5 mm
Damping zone (end point)	30.0 mm/ 36.0 mm/ 63.0 mm (depending on type)
Power-up delay	< 250 msec
Measuring frequency (internal)	1 ms
Transmission rate (cycle time)	CANopen (0 ... 65,535 ms) factory setting: 0 ms (transmission stopped) SAE J1939: 20 ms
Setpoint tolerance	≤ 1.0 mm
Zero point and F.S.[14]	≤ ± 1 mm
Solution	0.1 mm typical (noise-free)
Hysteresis	± 0.1 mm
Repeatability	Typ. ± 0.2 mm
Linearity (in operational status)	Typ. ± 0.25 mm (measuring range from 50 to 500 mm) Typ. ± 0.04% F.S. (Measuring range from 500 to 2,500 mm)
Temperature drift	
Self-heating of the electronics (warm-up phase)	Typ. ≤ ± 0.25 mm (2 min)
Operational status (hydraulic oil at operating temperature)	≤ ± 0.005% x F.S. x ΔT (ΔT 40 °C) [15]
MTTFd	69 years (EN ISO 13849-1) [16][17]

14) F.S. = Full scale (measuring range end value)
15) Rise in oil temperature by 40 °C during operation.
16) This product is a standard product and does not constitute a safety component as defined in the Machinery Directive. Calculation based on nominal load of devices, average ambient temperature of the electronics 60 °C, frequency of use 8,760h/a.
17) Every 2nd. failure of an electronic component is considered hazardous.

Interfaces	
Communication interface detailed	CANopen / SAE J1939
Bus protocol	CANopen CiA DS-301
Device profile	CANopen CiA DS-406
Network Management Protocol	SAE J1939-81
Application Layer	SAE J1939-71

Electrical data	
Connection type	M12 male connector, 5-pin
Supply voltage	
24 V DC	8 ... 36 V DC [18]
Residual ripple	< 1% p-p
Power consumption	
24 V DC	≤ 0.75 W
Current consumption	
24 V DC	≤ 30 mA
Load resistance	
Bus termination	120 Ω
Inrush current	
24 V DC	Typ. 5.0 A / 50 µs
Overvoltage protection	
12 V DC	≤ 18 V at all poles during power-up (60 s) ≤ 24 V to GND during power-up (60 s)
24 V DC	≤ 36 V at all poles during power-up (60 s) ≤ 48 V to GND during power-up (60 s)
Reverse polarity protection	≤ 36 V (at all poles) (ISO 16750-2)
Insulation resistance	R_{iso} ≥ 10 MΩ, 60 s (ISO 16750-2)
Dielectric strength	500 V DC (0 V to housing) (ISO 16750-2)

Mechanical data	
Dimensions	
Size	MAX48: 48f7 mm (for installation in a 48H8 bore hole) MAX30: 31f7 mm (for installation in a 31H8 bore hole)
ØPressure pipe	MAX48N/MAX48A: 10 mm MAX30N: 7 mm
ØO-ring	MAX48N/MAX48A: Ø 40.87 x 3.53 mm MAX30N: Ø 24.99 x 3.53 mm
ØSupport ring	MAX48N/MAX48A: Ø 48 x 42.6 x 1.4 mm MAX30N: Ø 31 x 25.8 x 1.4 mm
M12 flange type S	Construction DM 20x20 mm - hole pattern 14 mm (EN 61076-2-101)
M12 flange type L	Construction DM 24x24 mm - hole pattern 17 mm (EN 61076-2-101)
M12 male connector (strands)	60 ... 240 mm (depending on type)

18) 36 V only during power-up

Mechanical data	
Connecting cable / stripped strands	Ø5.0 mm / Ø 1.4 mm 300 ... 10.000 mm (depending on type) 3 x 0.38 mm^2 (AWG22)
Material	
Electronics housing	Stainless steel 1.4305, AISI 303
Pressure pipe	Stainless steel 1.4404, AISI 316L
O-ring	NBR 70
Support ring	PTFE
M12 plug insert	Glass fiber reinforced polyamide, nickel-/gold-plated brass contacts
M12 flange	Nickel-plated brass with O-ring (NBR)
Connecting cable / strands	PUR / PVC

Ambient data	
EMC	EU Directive 2014/30 / EU CE marking
Generic standards	MAX48N/MAX48A: EN 6100-6-2:2005 and EN 61000-6-3:2007 MAX30N: n.a.
Agricultural and forestry machinery, construction machinery	EN ISO 14982:2009 EN 13309:2010 / EN ISO 13766-1:2018
Transient pulses	ISO 7637-2
ESD (air and contact discharge)	EN 61000-4-2, ISO/TR 10605
Enclosure rating	
Housing	IP67 (EN 60529)
Housing with connecting cable / strands	IP67 (EN 60529)
M12 male connector	IP69k (ISO 20653) [19)]
Temperature	
Operating temperature range (electronics)	–40 °C ... +105 °C [20)]
Ambient temperature (fluid)	–30 °C ... +95 °C [21)]
Storage temperature range	–20 °C ... +65 °C [22)23)]
Permissible relative humidity	90% (condensation not permitted)
Resistance to shocks	Drop test according to IEC 60068-2-31 100 g, 11 ms (single shock in accordance with IEC 60068-2-27) 50 g, 11 ms (continuous shocks, 1,000 shocks per spatial axis in acc. with IEC 60068-2-27)
Resistance to vibrations	
Sine	MAX48N/MAX48A: 20 g, 24 h / spatial axis, 55 ... 2,000 Hz (IEC 60068-2-6) MAX30N: 15 g, 24 h / spatial axis, 55 ... 2,000 Hz (IEC 60068-2-6)
Sine-on-random	MAX48N/MAX48A:18 g (r.m.s), 36 h / spatial axis, 10 ... 2,000 Hz (IEC 60068-2-80) MAX30N: 13 g (r.m.s), 36 h / spatial axis, 10 ... 2,000 Hz (IEC 60068-2-80)

19) With suitable coupling (sealing through O-ring in coupling nut).
20) Taking into account self-heating generated through constant electrical operation with supply voltage.
21) Caused by the permitted temperature range of the O-ring seal, the hydraulic oil and the temperature-dependent signal quality of the position magnet.
22) Relative humidity 55%
23) Caused by dry storage of the O-ring in uninstalled state (no coating with oil).

Ambient data	
Noise (resonance peaks removed)	MAX48N/MAX48A: 20 g (r.m.s), 48 h / spatial axis, 10 ... 2,000 Hz (IEC 60068-2-64) MAX30N: 15 g (r.m.s), 48 h / spatial axis, 10 ... 2,000 Hz (IEC 60068-2-64)
Nominal operating pressure (PN)	MAX48N/MAX48A: 400 bar MAX30N: 320 bar
Max. overload pressure during operation (PN x 1.2)	MAX48N/MAX48A: 480 bar MAX30N: 380 bar
Max. test pressure in cylinder (PN x 1.5)	MAX48N/MAX48A: 600 bar MAX30N: 480 bar

10.3 Encoder dimensions

MAX48N

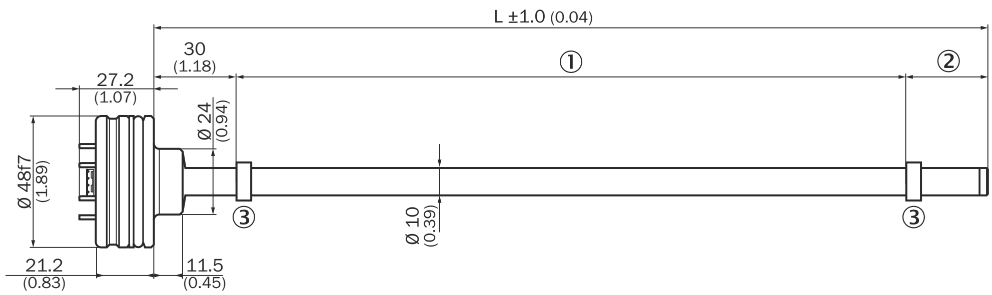


Figure 39: MAX48N housing without connecting cable / strands

① Measuring range
② Damping zone
③ Position magnet

MAX48A

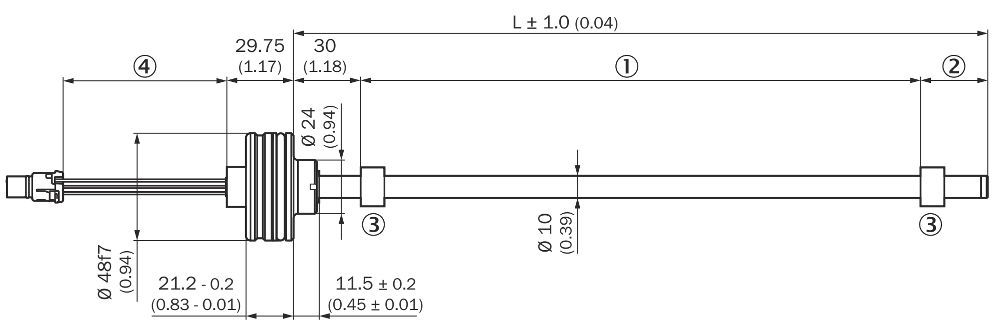


Figure 40: MAX48A housing with M12 male connector / strands

① Measuring range
② Damping zone
③ Position magnet
④ Strand length

MAX30N

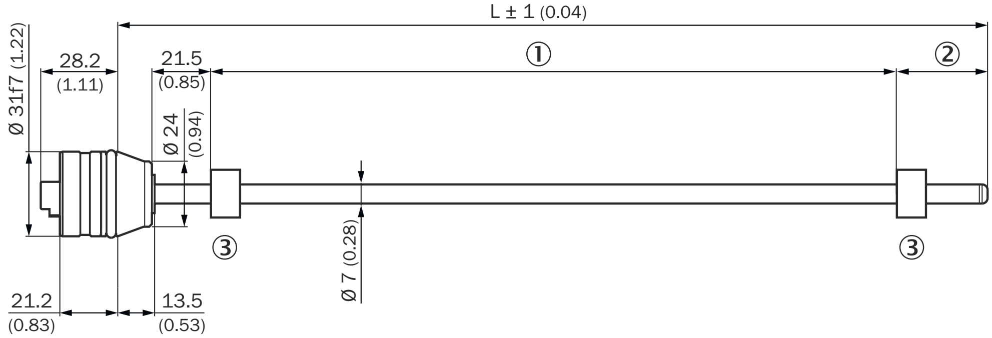


Figure 41: MAX30N housing without connecting cable / strands

① Measuring range
② Damping zone
③ Position magnet

10.4 Position magnet dimensions

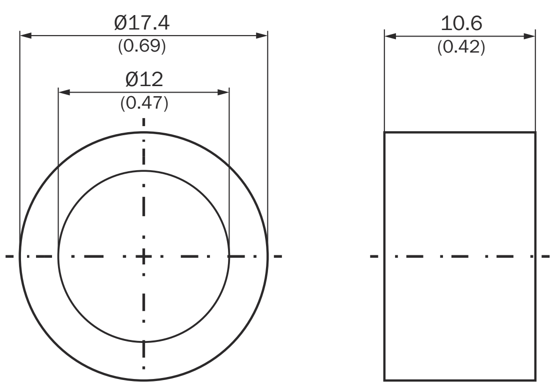


Figure 42: Dimensional drawing of position magnet MAG-0-174-xx, part number (packaging units 1, 5, 10 and 50): MAG-0-174-01, MAG-0-174-05, MAG-0-174-10, MAG-0-174-50

Table 43: Dimensions of position magnet

Outer diameter	17.4 mm
Inner diameter	12.0 mm
Height	10.6 mm

Max. surface pressure or mechanical load, e.g., by spring washers: 40 N/mm² in the axial direction.

10.5 M12 flange dimensions

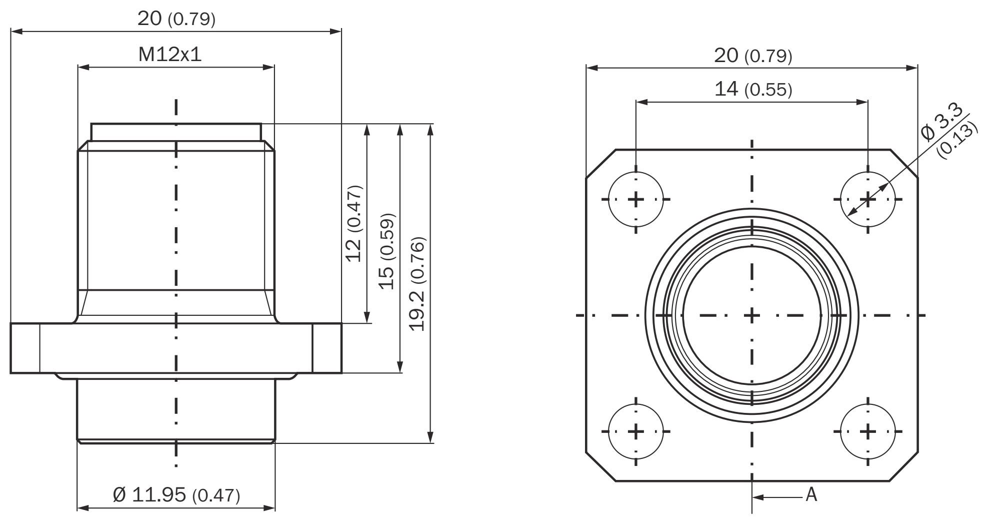


Figure 43: Dimensional drawing of square flange type S (BEF-FA-M12S-xx, part numbers (packaging units 1, 5 and 10): BEF-FA-M12S-01, BEF-FA-M12S-05, BEF-FA-M12S-10)

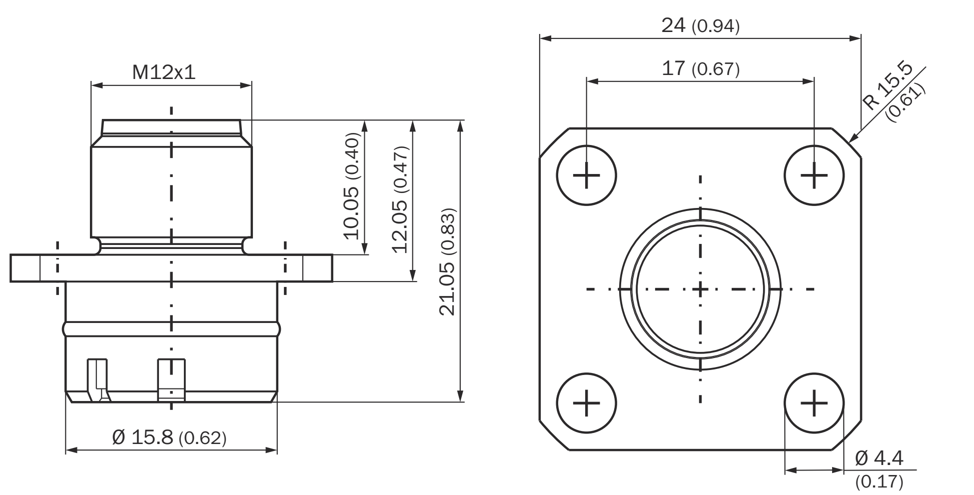


Figure 44: Dimensional drawing of square flange type L (BEF-FA-M12L-xx, part numbers (packaging units 1, 5 and 10): BEF-FA-M12L-01, BEF-FA-M12L-05, BEF-FA-M12L-10)

11 Annex

11.1 Accessories

Table 44: Electrical connection accessories (position magnet, corrugated spring washer, circlip)

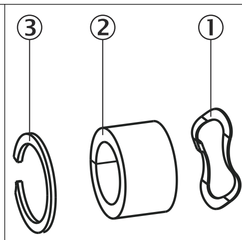
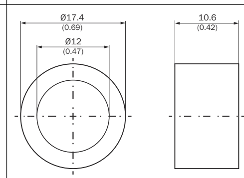
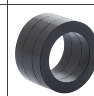
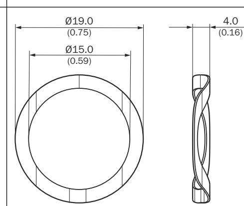
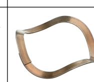
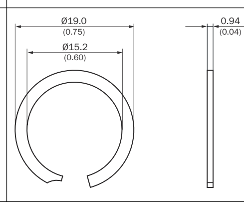
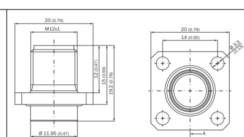
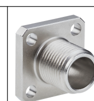
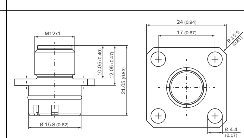
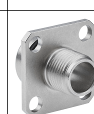
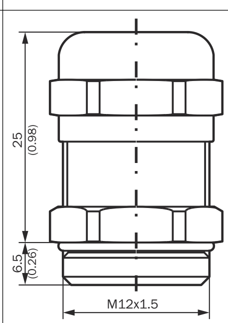
Order			① Corrugated spring washer ② Position magnet ③ Circlip
Position magnet			Not included with delivery. Available as accessory.
Corrugated spring washer			Not included with delivery. Available as accessory. (Smalley)
Circlip			Not included with delivery. Available as accessory. (Smalley)

Table 45: Electrical connection accessories (flange type S/L, cable gland)

M12 flange type S			Mounting: 4 x M3x6 screws Not included with delivery. Available as accessory.
M12 flange type L			Mounting: 4 x M4x6 screws Not included with delivery. Available as accessory.
Cable gland			Not included with delivery. Available as accessory.

NOTE
For spare part, see product pages of the MAX® www.sick.com/MAX® or product information:

- MAX48N product information: 8021724
- MAX48A product information: 8025846
- MAX30N product information: 8024963

11.2 Specification of additional components

O-ring

Included with delivery (installed). Not available as accessory. (Manufacturer: Parker)

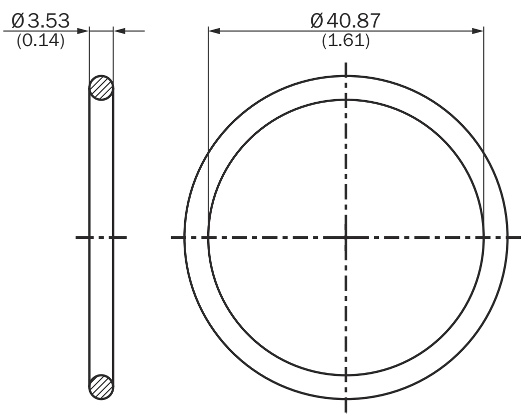


Figure 45: O-ring - MAX48N/MAX48A

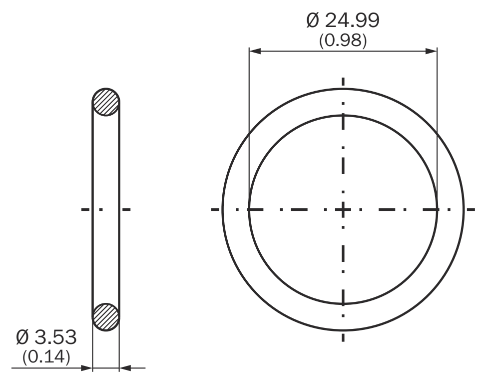


Figure 46: O ring – MAX30N

- Material: NBR 70
- Dimensions (MAX48N/MAX48A): 40.87 x 3.53
- Dimensions (MAX30N): 24.99 x 3.53

Support ring

Included with delivery (installed). Available as spare part (manufacturer Technoparts).

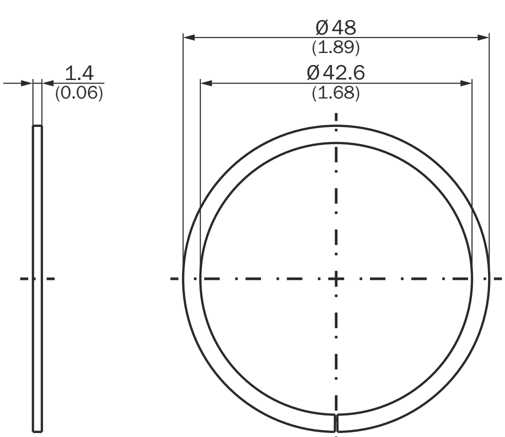


Figure 47: Support ring - MAX48N/MAX48A

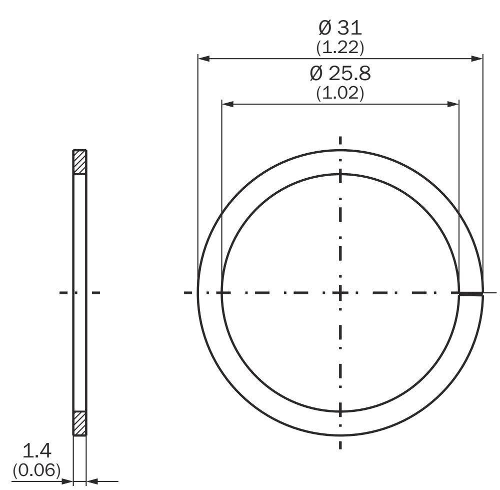


Figure 48: Support ring – MAX30N

- Material: PTFE
- Dimensions (MAX48N/MAX48A): 42.6 x 48.0 x 1.4
- Dimensions (MAX30N): 25.8 x 32.0 x 1.4

11.3 CE Declaration of Conformity

The CE Declaration of Conformity and other certificates can be downloaded from the Internet at:

- www.sick.com/MAX®

8022793/19KX/2021-03-08/en

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