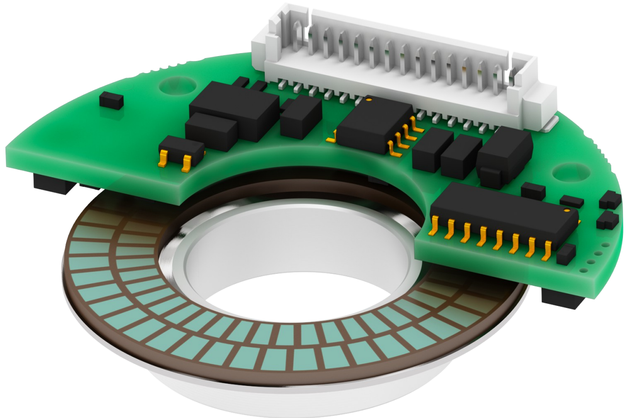
Smart encoders & actuators

User's guide

SMAR1



Incremental and absolute kit encoder

- Ultra-flat kit encoder with magnetic scanning
- Incremental TTL version + UVW commutation signals
- Absolute SSI, BiSS, & SPI interfaces + AB0 /AB0 signals
- Resolution up to 65,536 PPR (incr.) / 524,288 cpr (abs.)
- Direct integration into robots, motors, and OEM applications

Suitable for the following models:

- SMAR1-L1-000/...
- SMAR1-BG1-...
- SMAR1-SC1-...
- SMAR1-SP1-...

General contents

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Typographic and iconographic conventions

In this guide, to make it easier to understand and read the text the following typographic and iconographic conventions are used:

- parameters and objects both of Lika device and interface are coloured in **GREEN**;
- alarms are coloured in **RED**;
- states are coloured in **FUCSIA**.

When scrolling through the text some icons can be found on the side of the page: they are expressly designed to highlight the parts of the text which are of great interest and significance for the user. Sometimes they are used to warn against dangers or potential sources of danger arising from the use of the device. You are advised to follow strictly the instructions given in this guide in order to guarantee the safety of the user and ensure the performance of the device. In this guide the following symbols are used:

	This icon, followed by the word **WARNING**, is meant to highlight the parts of the text where information of great significance for the user can be found: user must pay the greatest attention to them! Instructions must be followed strictly in order to guarantee the safety of the user and a correct use of the device. Failure to heed a warning or comply with instructions could lead to personal injury and/or damage to the unit or other equipment.
	This icon, followed by the word **NOTE**, is meant to highlight the parts of the text where important notes needful for a correct and reliable use of the device can be found. User must pay attention to them! Failure to comply with instructions could cause the equipment to be set wrongly: hence a faulty and improper working of the device could be the consequence.
	This icon is meant to highlight the parts of the text where suggestions useful for making it easier to set the device and optimize performance and reliability can be found. Sometimes this symbol is followed by the word **EXAMPLE** when instructions for setting parameters are accompanied by examples to clarify the explanation.

Preliminary information

This guide is designed to provide the most complete and exhaustive information the operator needs to correctly and safely install and operate the **SMAR1 kit encoder.**
This encoder is available both in the SMAR1-L1-000/... version with incremental interface (Line Driver RS-422 signal level) and in the SMAR1-BG1-..., SMAR1-SC1-..., and SMAR1-SPI1-... versions with absolute interface (SSI, BiSS C-mode, and SPI interfaces respectively). The incremental version also provides additional UVW /UVW commutation signals (1 to 16 pole pairs) for brushless motor feedback. SSI and BiSS C-mode absolute versions can provide also additional AB0 /AB0 incremental signals (Line Driver signal level) for speed control. Incremental resolution is up to 16 bits (65,536 PPR). Absolute versions can be singleturn and multiturn, see the order code. For example: SMAR1-SC1-017/... is a 17 bit singleturn encoder; SMAR1-SC1-17M/... is a 17 + 16 bit multiturn encoder. Absolute resolution is up to 19 bit singleturn (524,288 cpr) and 16 bit multiturn (65,536 turns). It is ideal for direct integration into space critical applications such as robots, robotic joints, hollow shaft motors (direct drive torque motors, ...), brushless and servo motors, drones / UAVs, video surveillance systems, OEM equipment.

To make it easier to read and understand the text, this guide can be divided into some sections.
In the first section some general information concerning the safety, the mechanical installation and the electrical connection as well as tips for setting up and running properly and efficiently the unit are provided.
In the second section, entitled **Incremental & UVW signals**, both general and specific information is given on the incremental and UVW signals, see on page 22.
In the third section, entitled **SSI interface**, both general and specific information is given on the SSI interface, see on page 25.
In the fourth section, entitled **BiSS C-mode interface**, both general and specific information is given on the BiSS C-mode interface, see on page 29.
In the fifth section, entitled **SPI interface**, both general and specific information is given on the SPI interface, see on page 33.

1 - Safety summary

1.1 Safety

- Always adhere to the professional safety and accident prevention regulations applicable to your country during device installation and operation;
- installation and maintenance operations have to be carried out by qualified personnel only, with power supply disconnected and stationary mechanical parts;
- device must be used only for the purpose appropriate to its design: use for purposes other than those for which it has been designed could result in serious personal and/or the environment damage;
- high current, voltage and moving mechanical parts can cause serious or fatal injury;
- warning! Do not use in explosive or flammable areas;
- failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the equipment;
- Lika Electronic assumes no liability for the customer's failure to comply with these requirements.

1.2 Electrical safety

- Turn off the power supply before connecting the device;
- connect according to the explanation in the "4 - Electrical connections" section on page 16;
- the wires of unused output signals must be cut at different lengths and insulated singularly;
- (SMAR1 SSI and BISS absolute versions): connect the Zero setting input to 0Vdc if not used; to set the zero, connect Zero setting to +Vdc for 100 µs at least, then disconnect +Vdc; normally Zero setting voltage must be at 0Vdc; we suggest performing the zero setting when the encoder is in stop;
- in compliance with the 2014/30/EU norm on electromagnetic compatibility, the following precautions must be taken:
  - before handling and installing, discharge electrical charge from your body and tools which may come in touch with the device;
  - power supply must be stabilized without noise, install EMC filters on device power supply if needed;
  - always use shielded cables (twisted pair cables whenever possible);
  - avoid cables runs longer than necessary;
  - avoid running the signal cable near high voltage power cables;
  - mount the device as far as possible from any capacitive or inductive noise source, shield the device from noise source if needed;
  - to guarantee a correct working of the device, avoid using strong magnets on or near by the unit;
  - minimize noise by connecting the shield and/or the frame to ground. Make sure that ground is not affected by noise. The connection point to ground can be situated both on the device side and on user's side. The best solution to minimize the interference must be carried out by the user.

1.3 Mechanical safety

- Install the device following strictly the information in the "3 - Mounting instructions" section on page 12;
- mechanical installation has to be carried out with stationary mechanical parts;
- do not disassemble the encoder;
- do not tool the encoder or its shaft;
- delicate electronic equipment: handle with care; do not subject the device and the shaft to knocks or shocks;
- protect the unit against acid solutions or chemicals that may damage it;
- respect the environmental characteristics declared by manufacturer;
- the encoder and the disk must be adequately protected in order to be able to cope with the industrial environment where they are to be installed;
- we suggest installing the unit providing protection means against waste, especially swarf as turnings, chips, or filings; should this not be possible, please make sure that adequate cleaning measures (as for instance brushes, scrapers, jets of compressed air, etc.) are in place in order to prevent the sensor and the magnetic ring from jamming.

1.4 Specific handling and cleaning instructions and safety information against electrostatic discharges

Please be sure to strictly observe the following safety precautions and instructions before handling and installing the kit encoder.

- Open the box and handle the electronic components only within an EPA (Electrostatic Protective Area) and when you are properly grounded;
- before handling the kit encoder the operator must wear:
  - a wrist strap; it must be worn on the hand and connected to ground through a 1 megohm resistor;
  - an ESD smock made of dissipative material;
  - dissipative gloves; they are further used not to dirty the code disk while mounting;
- always handle the encoder by grasping the plastic enclosure on the sides;
- the code disk must always be handled by grasping its outer edges;

- avoid flexing the disk, exposing it to direct sunlight, excessive heat and/or humidity;
- if dust gets on to the disk, wipe with a soft dry cloth; wipe the disk using circular motions; more stubborn stains can be removed using a soft cloth lightly moistened with a few drops of alcohol; do not use gasoline, kerosene, benzene or other solvents, as they damage the disk.

CAUTION
Keep magnets away from the ring, it could be damaged by strong magnetic fields.

2 - Identification

Device can be identified through the **order code** and the **serial number** printed on the label applied to its body. Information is listed in the delivery document too. Please always quote the order code and the serial number when reaching Lika Electronic. For any information on the technical characteristics of the product refer to the technical catalogue.

Warning: encoders having order code ending with "/Sxxx" may have mechanical and electrical characteristics different from standard and be supplied with additional documentation for special connections (Technical Info).

3 - Mounting instructions

WARNING
Installation must be carried out by qualified personnel only, with power supply disconnected and mechanical parts compulsorily in stop.

WARNING
Before handling and mounting the device please be sure to read carefully the handling instructions and safety information reported in the "1.4 Specific handling and cleaning instructions and safety information against electrostatic discharges" section on page 9.

WARNING
Install the unit providing protection means against waste, especially swarf as turnings, chips or filings; should this not be possible, please make sure that adequate cleaning measures (as for instance brushes, scrapers, jets of compressed air, etc.) are in place in order to prevent the sensor and the magnetic ring from jamming.
Make sure the mechanical installation meets the system's requirements for both the sensor and the ring indicated in this guide.

3.1 Encumbrance sizes

(values are expressed in mm)

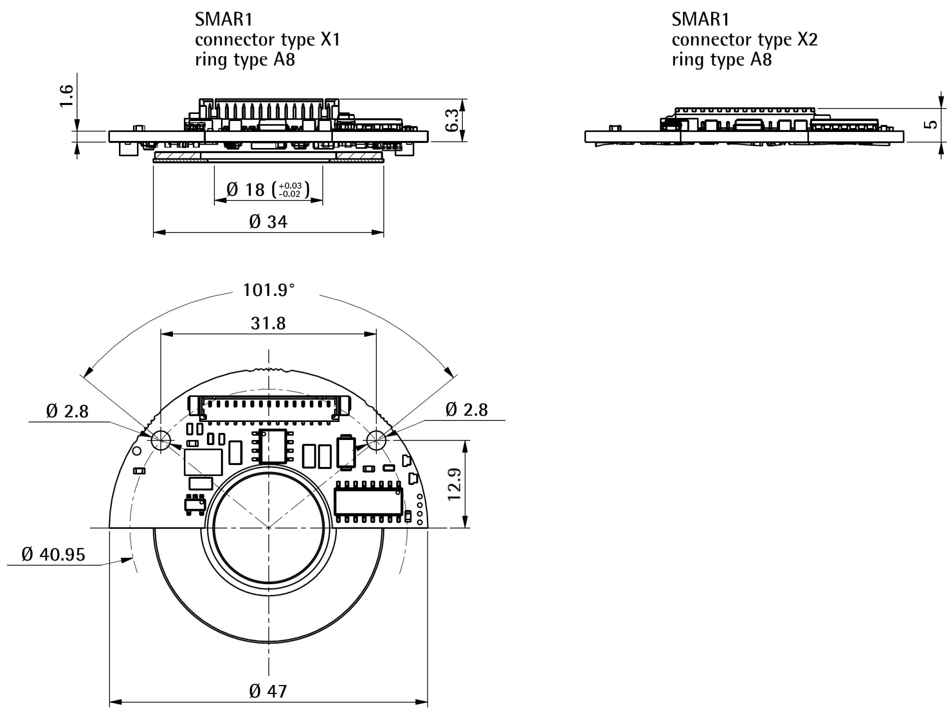
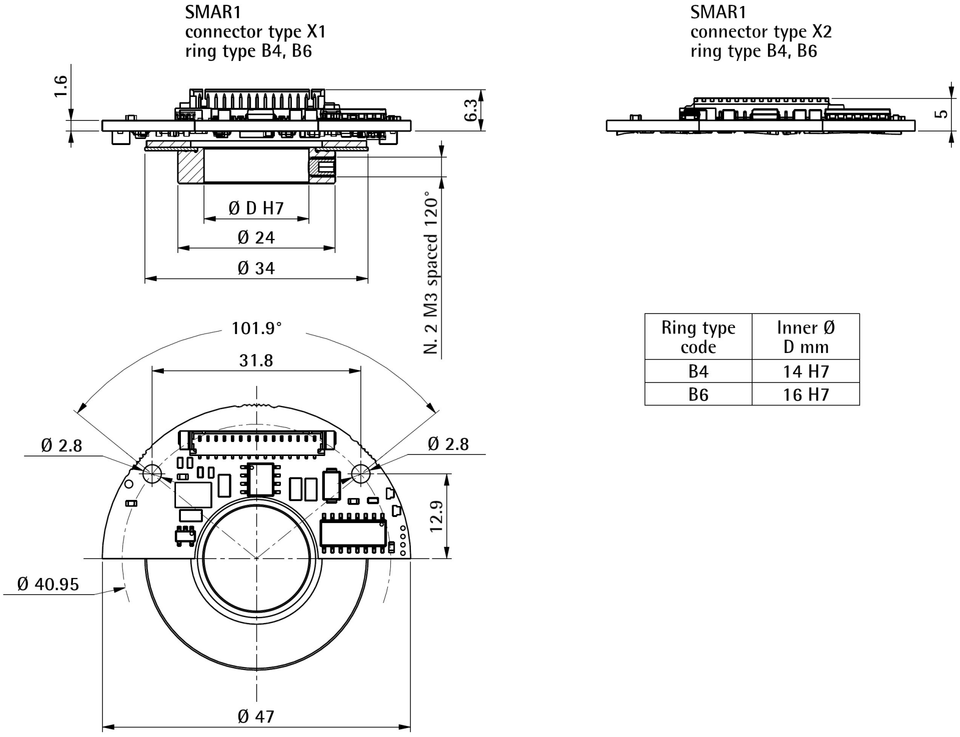
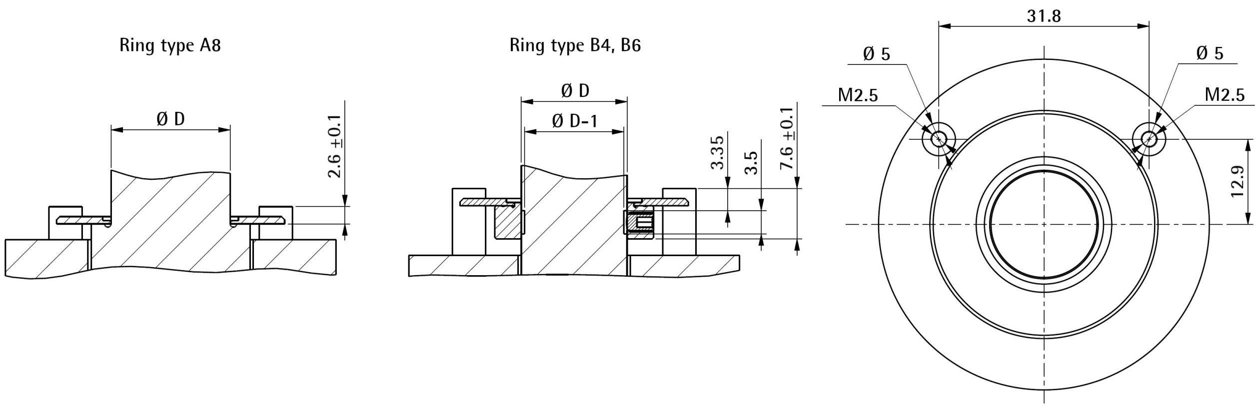


Figure 1 - SMAR1 + MRA34A without mounting mechanical support



Ring type code	Inner Ø D mm
B4	14 H7
B6	16 H7

Figure 2 - SMAR1 + MRA34B with mounting mechanical support



Ring type code	Shaft Ø D mm
A8	$18\,(^{-0.022}_{-0.035})$
B4	14 g6
B6	16 g6

Figure 3 - Mounting requirements

3.2 Mounting the code disk

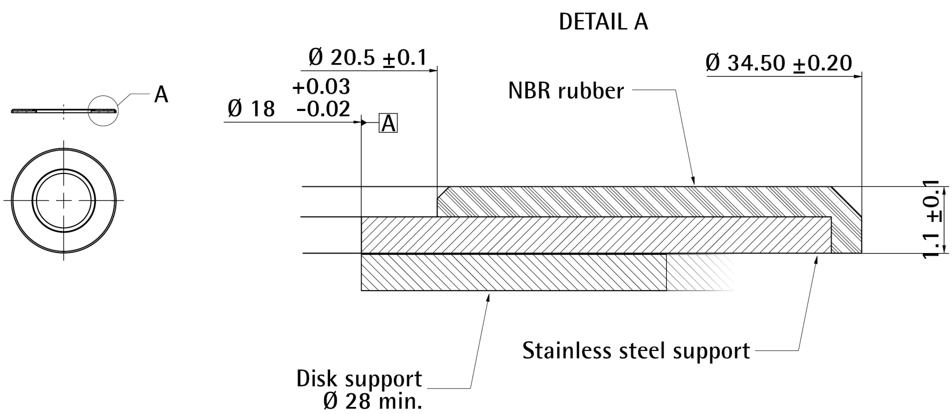
WARNING

- To clean the code disk from dust, wipe it with a soft dry cloth; more stubborn stains can be removed using a soft cloth lightly moistened with a few drops of alcohol; do not use gasoline, kerosene, benzene or other solvents;
- the code disk must always be handled by grasping its outer edges;
- protect the disk from scratching;
- avoid flexing the disk;
- always handle the encoder unit by grasping the PCB on the sides.

3.2.1 Code disk without disk mounting mechanical support

It is the customer's responsibility to identify the assembly method that is most suitable for his own application.

(values are expressed in mm)



The coded layer is made up of NBR elastomer rubber (acrylonitrile butadiene rubber) with incorporated magnetic filler. It is mounted on a 0.6 mm thick AISI 430 stainless steel support.
Please note that the disk support must have 28 mm minimum diameter in order to support the disk properly and keep the concentricity of the coded tracks.
For bonding and cleaning please consider the physical characteristics of the materials mentioned above.

3.2.2 Code disk with disk mounting mechanical support

Insert the code disk into the drive shaft; always handle the code disk by grasping its outer edges. Tighten the **two M3 x 3 UNI5929 grub screws** to firmly fasten the code disk; the max. tightening torque is **1.3 Nm**. Please consider the mounting tolerances shown in Figure 4.

3.3 Mounting the encoder

WARNING
Always handle the encoder unit by grasping the PCB on the sides.

Mount the encoder unit **1** over the code disk **2**; make sure that the encoder unit **1** does not hit or touch the code disk **2**; check the mounting tolerances shown in the Figure below; always handle the encoder unit **1** by grasping its outer edges. Insert the **M2.5 x 6 cylinder-head bolts** in the holes **3**, tighten both bolts down to firmly fix the encoder unit **1**, torque to **0.7 Nm** max. Hold the encoder unit **1** down and avoid any movements while tightening.

Finally connect the **EC-X15-LK-KT16-L010** cable to the Molex connector of the encoder unit **1**.

WARNING
The encoder and the disk must be adequately protected in order to be able to cope with the industrial environment where they are to be installed.

CAUTION
Keep magnets away from the ring, it could be damaged by strong magnetic fields.

(values are expressed in mm)

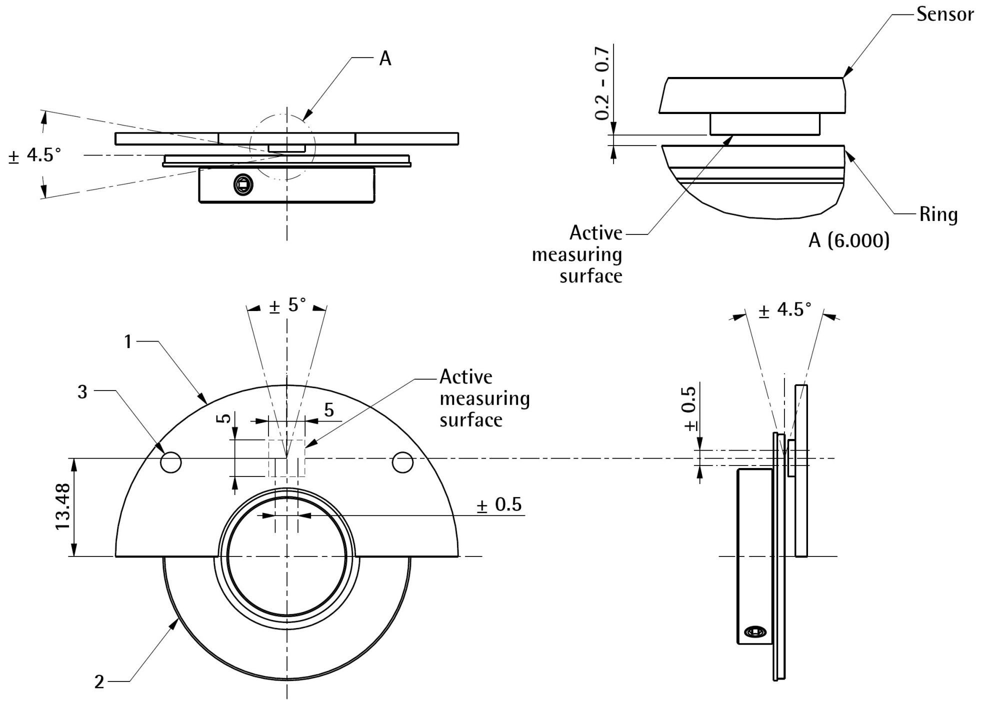
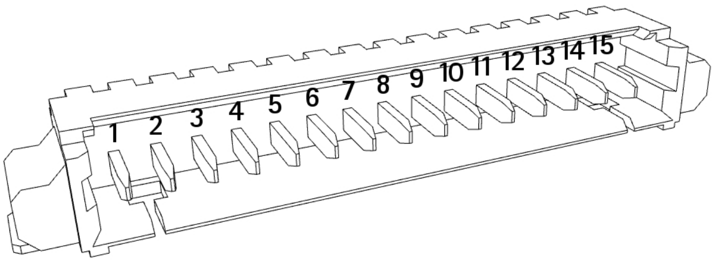


Figure 4 - Mounting the encoder

4 - Electrical connections

WARNING
Power supply must be turned off before performing any electrical connection!
If wires of unused signals come in contact, irreparable damage could be caused to the device. Thus they must be cut at different lengths and insulated singularly.

4.1 Molex 53261-1571 connector



Mating connector: Molex 51021-1500

4.1.1 Connection of the SMAR1 L1 incremental encoder

The following pinout refers to the order code: SMAR1-L1-000/...

Function	Pin
Shield	1
0Vdc	2
+5Vdc ±5%	3
B	4
A	5
0	6
/B	7
/A	8
/0	9
U	10
V	11
W	12
/U	13
/V	14
/W	15

4.1.2 Connection of the SMAR1 SSI / BISS encoder

The following pinout refers to the order codes: SMAR1-BG1-... and SMAR1-SC1-...

Function	Pin
Shield	1
0Vdc	2
+5Vdc ±5%	3
Clock IN + / MA +	4
Data OUT + / SLO +	5
Zero setting	6
Clock IN - / MA -	7
Data OUT - / SLO -	8
not connected	9
B	10
A	11
0	12
/B	13
/A	14
/0	15

4.1.3 Connection of the SMAR1 SPI encoder

The following pinout refers to the order code: SMAR1-SP1-...

Function	Pin
Shield	1
0Vdc	2
+5Vdc ±5%	3
SCLK	4
MISO	5
CS	6
not connected	7
MOSI	8
not connected	9
not connected	10
not connected	11
not connected	12
not connected	13
not connected	14
not connected	15

4.2 Cable connections

EC-X15-LK-KT16-Lxxx cable (EC-X15-LK-AW15-x cable)

4.2.1 SMAR1 L1 incremental encoder wiring

The following wire connection refers to the order code: SMAR1-L1-000/...

Function	15-wire cable
Shield	Shield
0Vdc	White_Green
+5Vdc ± 5%	Brown_Green
A	Green
B	White
0	Pink
/A	Yellow
/B	Brown
/0	Grey
U	Red
V	Violet
W	Grey_Pink
/U	Blue
/V	Black
/W	Red_Blue

4.2.2 SMAR1 SSI / BISS encoder wiring

The following wire connection refers to the order codes: SMAR1-BG1-... and SMAR1-SC1-...

Function	15-wire cable
Shield	Shield
0Vdc	White_Green
+5Vdc ±5%	Brown_Green
Clock IN + / MA +	White
Data OUT + / SLO +	Green
Zero setting	Pink
Clock IN - / MA -	Brown
Data OUT - / SLO -	Yellow
not connected	Grey
A	Violet
B	Red
0	Grey_Pink
/A	Black
/B	Blue
/0	Red_Blue

4.2.3 SMAR1 SPI encoder wiring

The following wire connection refers to the order code: SMAR1-SP1-...

Function	15-wire cable
Shield	Shield
0Vdc	White_Green
+5Vdc ±5%	Brown_Green
SCLK	White
MISO	Green
NCS	Pink
not connected	Brown
MOSI	Yellow
not connected	Grey
not connected	Violet
not connected	Red
not connected	Grey_Pink
not connected	Black
not connected	Blue
not connected	Red_Blue

4.3 Connection of the shield

For signals transmission always use shielded cables. The cable shielding must be connected properly to ensure earthing.

4.4 Ground connection

Minimize noise by connecting the shield and/or the frame of the measuring system to ground. See above for the pins/wires to be used for shield connection. The two fixing points **3** (see Figure 4) can be used for ground connection, they provide a metal surface in both top and bottom layers. Make sure that ground is not affected by noise.

4.5 Incremental signals

For complete information on incremental signals please refer to the "5 - Incremental & UVW signals" section on page 22.

4.6 UVW commutation signals

For complete information on UVW commutation signals please refer to the "5.3 Commutation signals" section on page 23.

4.7 SSI interface

For complete information on the SSI interface please refer to the "6 - SSI interface" section on page 25.

4.8 BiSS C-mode interface

For complete information on the BiSS C-mode interface please refer to the "7 - BiSS C-mode interface" section on page 29.

4.9 SPI interface

For complete information on the SPI interface please refer to the "8 - SPI interface" section on page 33.

4.10 Absolute resolution

SMAR1 measuring system with absolute interface can have a singleturn resolution of 32,768 cpr (15 bits), 131,072 cpr (17 bits), 262,144 cpr (18 bits), and 524,288 cpr (19 bits).
The angular resolution is 0.01098° (0° 0' 40") for 15-bit model.
It is 0.00274° (0° 0' 10") for 17-bit model.
It is 0.00137° (0° 0' 5") for 18-bit model.
It is 0.00068° (0° 0' 2.5") for 19-bit model.

NOTE
To convert the absolute position value detected by the encoder into an angular position use the following formula:
1 STEP = 360° / 32,768 cpr = 0.01098 °
angular position = position value * 1 step

EXAMPLE
Position value = 3,000
Angular position = 3,000 * 0.01098 = 32.94° = 32° 56' 24"

4.11 Counting direction

The **standard counting direction** is to be intended with ring turning as indicated by the arrow in Figure 5. When the ring turns in the direction indicated by the arrow, in the absolute measuring system the count is up; in the incremental measuring system the rising edge of A signal leads the rising edge of B signal. The counting direction cannot be changed.

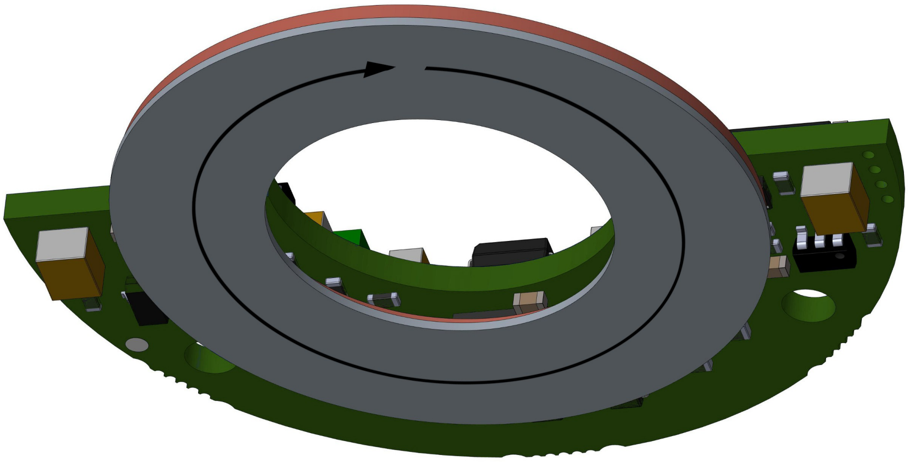


Figure 5 - Counting direction

4.12 Zero setting input

(SMAR1-BG1-... and SMAR1-SC1-... only)

The output position information at a decided point in the shaft rotation can be set to 0. The Zero setting input allows the operator to activate the zero value through an input signal sent by a PLC or other controller. This can be very useful for setting -for instance- the zero position of both the sensor and the machine. If not used, connect the Zero setting input to 0Vdc. To activate the zero setting function, connect the Zero setting input to +Vdc for 100 µs at least, then disconnect +Vdc; normally voltage must be at 0Vdc. We suggest setting the zero when the ring is in stop.

CAUTION

Keep magnets away from the ring, it could be damaged by strong magnetic fields.

4.13 Diagnostic LEDs

For complete information on the diagnostic LEDs please refer to the "9 - Diagnostic LEDs" section on page 42.

5 - Incremental & UVW signals

5.1 AB signals

SMAR1-L1-000/... measuring system as well as specific models of SMAR1-BG1-... and SMAR1-SC1-... measuring systems (see the order code) provide incremental signals AB0 /AB0 (the incremental resolution expressed in PPR can be read in the order code; for example: SMAR1-L1-000/**65536**-... = 65,536 PPR; SMAR1-BG1-017/**01024**-... = 1,024 PPR; SMAR1-SC1-019-/**04096**-... = 4,096 PPR; SMAR1-SP1-017/**00000**-... = incremental signals are not provided). The resolution of incremental signals AB0 /AB0 for each singleturn cycle can be within a range of 1 to 65,536 PPR.
The output circuit is Line Driver / Line Driver (RS-422)/TTL level type. It is operated at 5Vdc ±5% and the signal amplitude is in compliance with EIA RS-422 standard. It provides AB0 /AB0 signals.

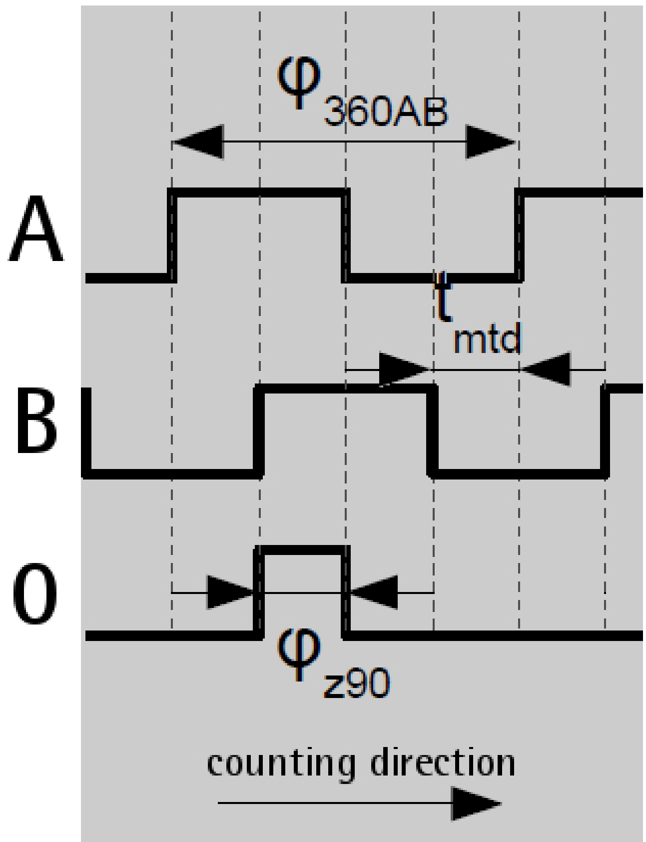


Figure 6 - Output signals

Figure 6 shows AB0 signals. The length of A / B signal cycles is defined by φ360AB as a range between two rising edges of an A or B signal.
The length of 0 pulse (φZ90) is 90 electrical degrees. The position of the Index pulse in relation to A/B signals is shown in Figure 6.
The minimum edge distance t_{mtd} of AB0 is 80 ns and the output frequency is up to 3 MHz.

The conversion electronics inside the sensor translates the magnetic fields of the ring into Line Driver level AB electrical signals.
The frequency of the output signals is proportional to the measuring speed while the number of output pulses is proportional to the mechanical displacement of the ring.

5.2 Reference signal

The Reference signal (0, /0) provides a single datum position in the revolution of the ring for use at power-up or following a loss of power. The signal is synchronized with A and B channels and has a duration of one measuring step (90 electrical degrees), see Figure 6. The amplitude is according to the power supply voltage level (Line Driver +5Vdc ±5% is in compliance with EIA RS-422 standard).

5.3 Commutation signals

SMAR1-L1-000/... version incremental encoder also generates commutation signals for BLDC motors from 1 up to 16 pole pairs. The number of pole pairs can be read in the order code.

EXAMPLE
SMAR1-L1-000/01024-**02**...: 2 = two poles = 1 pole pair
...
SMAR1-L1-000/01024-**32**...: 32 = thirty-two poles = 16 pole pairs

Figure 7 shows the commutation sequence for a motor with 6 pole pairs. A commutation sequence spanning an angle of φ360UVW is repeated six times within one mechanical revolution of the motor. The phase shift between the commutation signals is 120°.

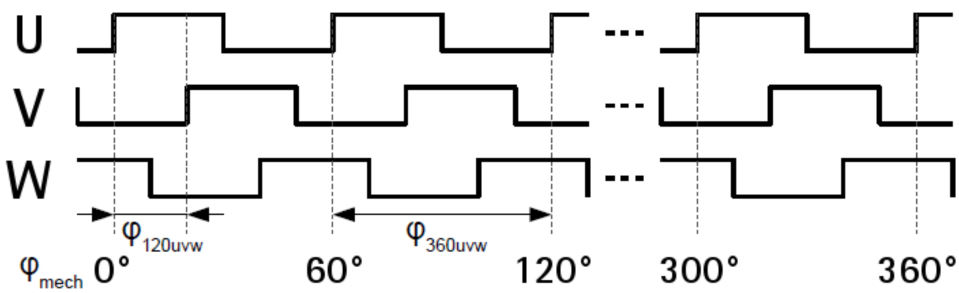
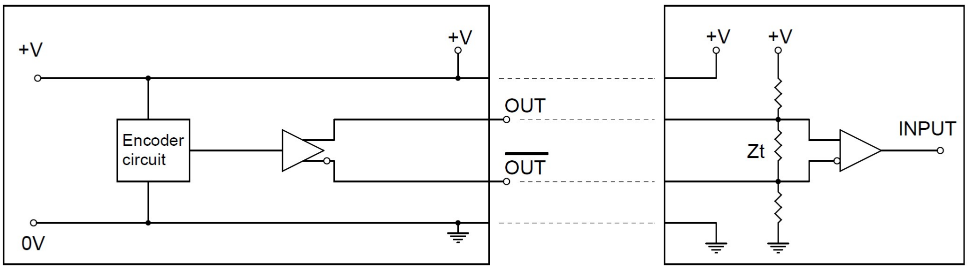


Figure 7 - UVW commutation signals

5.4 Recommended Line Driver incremental input circuit



6 - SSI interface

Order code:
SMAR1-BG1-... SSI Binary + Line Driver incremental output

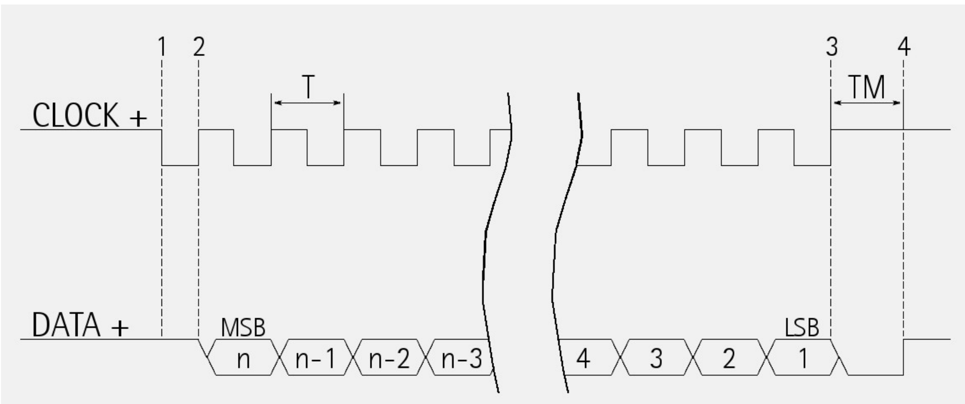
6.1 SSI (Synchronous Serial Interface) – General Information

SSI (the acronym for **Synchronous Serial Interface**) is a synchronous point-to-point serial interface engineered for unidirectional data transmission between one Master and one Slave. Developed in the first eighties, it is based on the RS-422 serial standard. Its most peculiar feature is that data transmission is achieved by synchronizing both the Master and the Slave devices to a common clock signal generated by the controller; in this way the output information is clocked out at each controller's request. Furthermore only two pairs of twisted wires are used for data and clock signals, thus a six-wire cable is required.
The main advantages in comparison with parallel or asynchronous data transmissions are:

- less conductors are required for transmission;
- less electronic components;
- possibility of insulting the circuits galvanically by means of optocouplers;
- high data transmission frequency;
- hardware interface independent from the resolution of the absolute encoder.

Furthermore the differential transmission increases the noise immunity and decreases the noise emissions. It allows multiplexing from several encoders, thus process controls are more reliable with simplified line design and easier data management.

Data transmission is carried out as follows.
At the first falling edge of the clock signal (**1**, the logic level changes from high to low) the absolute position value is stored while at the following rising edge (**2**) the transmission of data information begins starting from the MSB.



At each change of the clock signal and at each subsequent rising edge (**2**) one bit is clocked out at a time, up to LSB, so completing the data word transmission. The cycle ends at the last rising edge of the clock signal (**3**). This means that up to n + 1 rising edges of the clock signals are required for each data word transmission (where n is the bit resolution); for instance, a 13-bit encoder needs 14 clock edges. If the number of clocks is greater than the number of bits of the data word, then the system will send a zero (low logic level signal) at each additional clock, zeros will either lead (LSB ALIGNED protocol) or follow (MSB ALIGNED protocol) or lead and/or follow (TREE FORMAT protocol) the data word. After the period Tm monoflop time, having a typical duration of 16 µsec, calculated from the end of the clock signal transmission, the encoder is then ready for the next transmission and therefore the data signal is switched high.
The clock signal has a typical logic level of 5V, the same as the output signal which has customarily a logic level of 5V in compliance with RS-422 standard.
The output code can be either Binary or Gray (see the order code).

6.2 MSB Left Aligned protocol

"MSB Left Aligned" protocol allows to left align the bits, beginning from MSB (most significant bit) to LSB (least significant bit); LSB is then sent at the last clock cycle. If the number of clock signals is higher than the data bits, then unused bits are forced to logic level low (0) and follow the data word. This protocol can be used in sensors having any resolution.
The word has a variable length according to resolution, as shown in the following table.

Order code	Encoder resolution	Length of the word	Max. number of absolute information
SMAR1-BG1-017/...	17 bits	18 bits	131,072 info/rev.
SMAR1-BG1-018/...	18 bits	19 bits	262,144 info/rev.
SMAR1-BG1-019/...	19 bits	20 bits	524,288 info/rev.
SMAR1-BG1-15M/...	15 + 16 bits	32 bits	2,147,483,648 info
SMAR1-BG1-17M/...	17 + 16 bits	34 bits	8,589,934,592 info
SMAR1-BG1-18M/...	18 + 16 bits	35 bits	17,179,869,184 info
SMAR1-BG1-19M/...	19 + 16 bits	36 bits	34,359,738,368 info

The output code of the sensor is BINARY.

The transmitted position value has the following structure:

	Bit structure			
SMAR1-BG1-017/...	**17**	**...**	**1**	**0**
SMAR1-BG1-018/...	**18**	**...**	**1**	**0**
SMAR1-BG1-019/...	**19**	**...**	**1**	**0**
SMAR1-BG1-15M/...	**31**	**...**	**1**	**0**
SMAR1-BG1-17M/...	**33**	**...**	**1**	**0**
SMAR1-BG1-18M/...	**34**	**...**	**1**	**0**
SMAR1-BG1-19M/...	**35**	**...**	**1**	**0**
order code	MSB	...	LSB	Error bit

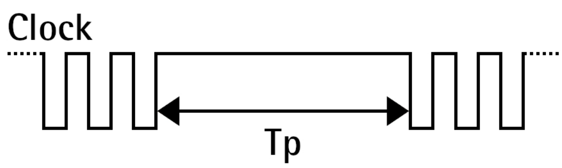
6.3 Recommended transmission rates

The SSI interface has a frequency of data transmission ranging between 100 kHz and 2 MHz.
The CLOCK IN and the DATA OUT signals comply with the "EIA standard RS-422".

The clock frequency (baud rate) depends on the length of the cable and must comply with the technical information reported in the following table:

Cable length	Baud rate
< 50 m	< 400 kHz
< 100 m	< 300 kHz
< 200 m	< 200 kHz
< 400 m	< 100 kHz

The time interval between two Clock sequence transmissions must be at least 20 µs (Tp = pause time > 20 µs).



6.4 Error bit

The error bit is intended to communicate the normal or fault status of the Slave.

"1": correct status (the sensor is working properly, there are no active errors)

"0": an error is active. For any information on the available errors and their solution please refer to the "10 – Warnings and errors" section on page 43.

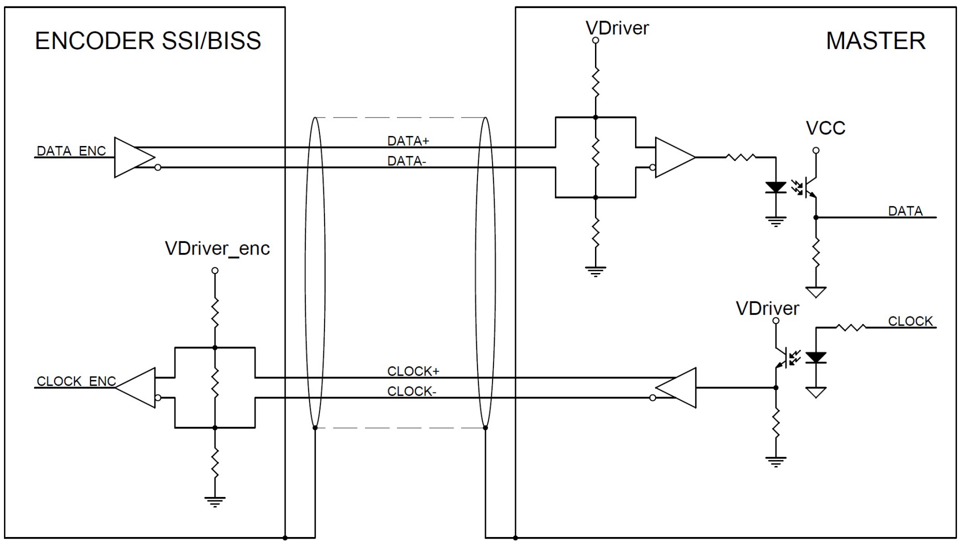
NOTE

For any information on the structure of the position information word, please refer to the "6.2 MSB Left Aligned protocol" section on page 26.

6.5 Helpful information

- The position information increases when the ring rotates as indicated by the arrow in Figure 5.
- At installation always execute a zero setting operation of the absolute position in the subsequent electronics.

6.6 Recommended SSI input circuit



7 - BiSS C-mode interface

Order code:
SMAR1-SC1-... BiSS C-mode + Line Driver incremental output

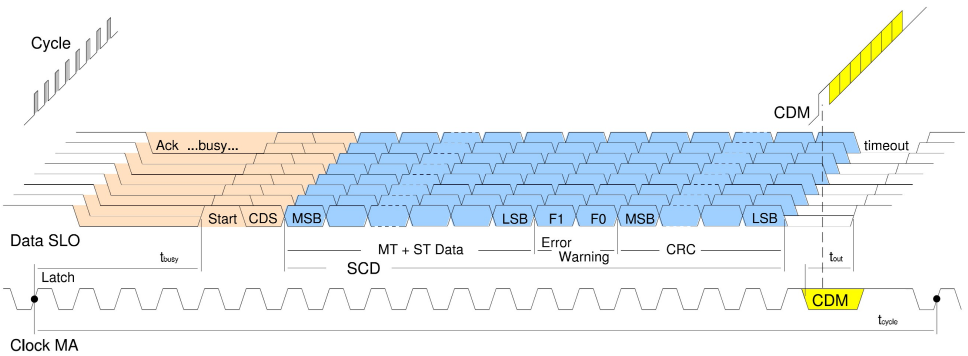
Lika encoders are always Slave devices and comply with the "BiSS C-mode interface" and the "Standard encoder profile".
Refer to the official BiSS website for all information not listed in this manual (www.biss-interface.com).
The device is designed to work in a point-to-point configuration and must be installed in a "single Master, single Slave" network.
CLOCK IN (MA) and DATA OUT (SLO) signal levels are according to the "EIA standard RS-422".

WARNING
Never install the encoder in a "single Master, multi Slave" network.

7.1 Communication

The BiSS C-mode protocol uses one data transmission protocol:

- **Single Cycle Data (SCD):** it is the main data transmission protocol. It is used to send process data from the Slave to the Master. For any information refer to the "7.2 Single Cycle Data SCD" section on page 30.



7.2 Single Cycle Data SCD

7.2.1 SCD structure

SCD data has a variable length according to the resolution of the encoder. It is nbitres+7 long where "nbitres" is the resolution of the encoder expressed in bits. It consists of the following elements: position value (**Position**), 1 error bit nE (**Error**), 1 warning bit nW (**Warning**) and a 6-bit CRC Cyclic Redundancy Check (**CRC**).

bit	nbitres+7 … 8	7	6	5 … 0
function	Position	Error	Warning	CRC

Position

It is the process data transmitted from the Slave to the Master. It has a variable length, it is as long as the resolution of the encoder expressed in bits.
It provides information about the current position of the encoder.
The transmission starts with msb (most significant bit) and ends with lsb (least significant bit).

bit	Nbitres+7	…	…	8
value	msb	…	…	lsb

"Nbitres" is the resolution of the encoder expressed in bits. It is comprised between 17 bits and 35 bits as shown in the following table.

Order code	Encoder resolution
SMAR1-SC1-017/…	17 bits
SMAR1-SC1-018/…	18 bits
SMAR1-SC1-019/…	19 bits
SMAR1-SC1-15M/…	15 + 16 bits
SMAR1-SC1-17M/…	17 + 16 bits
SMAR1-SC1-18M/…	18 + 16 bits
SMAR1-SC1-19M/…	19 + 16 bits

Error

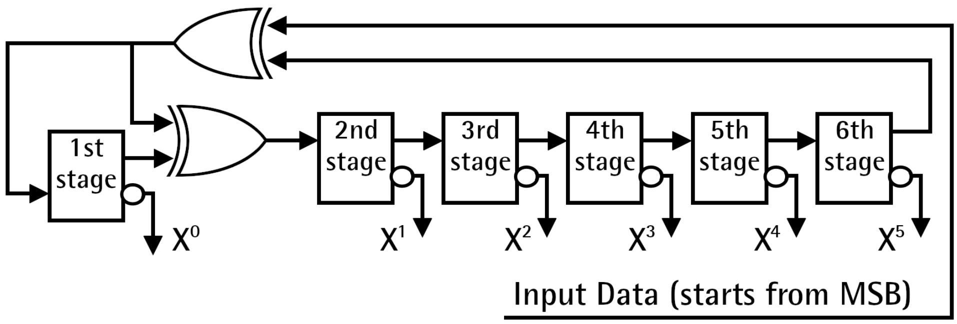
(1 bit)
It is intended to communicate the normal or fault status of the Slave.
When nE = "0" (low active), an error is active in the system. For a comprehensive list of the available error messages and their meaning please refer to the "10 – Warnings and errors" section on page 43.

nE = "1": no active error
= "0": error status: an error is active in the system.

Warning
(1 bit)
It is intended to communicate the normal or fault status of the Slave.
When nW = "0" (low active), a warning is active in the system. For a comprehensive list of the available warning messages and their meaning please refer to the "10 – Warnings and errors" section on page 43.
nW = "1": no active warning
= "0": warning status: a warning is active in the system.

CRC
Correct transmission control (inverted output). Cyclic Redundancy Check is an error checking which is the result of a "Redundancy Check" calculation performed on the message contents. This is intended to check whether transmission has been performed properly. It is 6-bit long.
Polynomial: X^6+X^1+1 (binary: 1000011)

Logic circuit

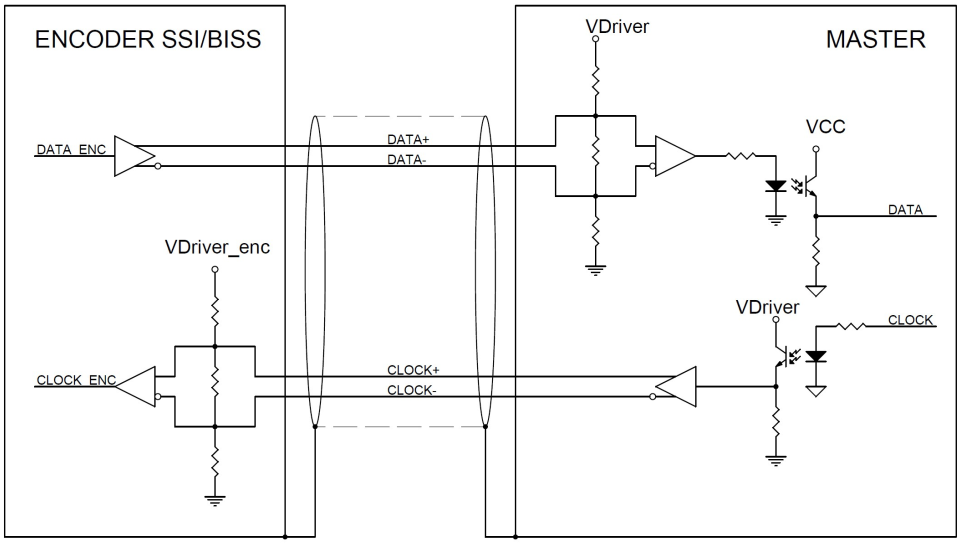


7.3 Application notes

Data transmission:

Parameter	Value
Clock Frequency	min 200 kHz, max 5 MHz
BiSS time-out	Self-adaptable to the clock, 0.3 µs min., 8 µs max.

7.4 Recommended BiSS input circuit



8 - SPI interface

Order code:
SMAR1-SP1-... SPI

8.1 Introduction to SPI interface

SPI is the acronym of Serial Peripheral Interface. It is one of the most widely used interfaces between microcontroller and peripheral ICs such as sensors, ADCs, DACs, shift registers, SRAM, and others. SPI is a synchronous, full duplex Master-Slave-based interface. Lika encoders are always Slave devices and support SPI modes 0 and 3. The data from the Master or the Slave is synchronized with the rising edge of the clock SCLK and the idle polarity of SCLK is insignificant. Although the SPI has become a de facto standard, it is not a de jure standard; in other words, it is not officially specified.

8.2 Interface

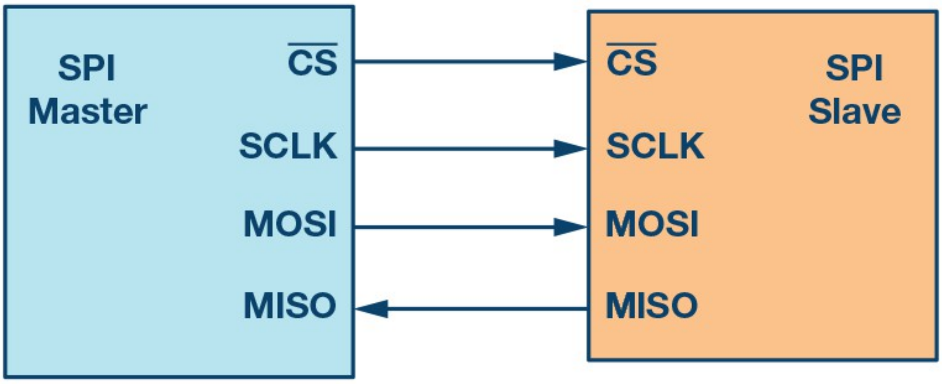


Figure 8 - SPI configuration with Master and one Slave

The SPI bus consists of four unidirectional wires.
Lika encoders are 4-wire SPI devices and carry the following signals:

- Clock: SPI CLK, SCLK
- Interface enable: Chip Select (CS)
- Data IN: MOSI (Master OUT, Slave IN)
- Data OUT: MISO (Master IN, Slave OUT)

8.2.1 SCLK SPI Clock signal

The device that generates the clock signal is called the Master. Data transmitted between the Master and the Slave is synchronized to the clock generated by the Master. As stated, SPI modes 0 and 3 are supported, i.e. idle level of SCLK is either 0 or 1 and data is accepted on a rising edge.

The mode depends on the SCLK level, sometimes called polarity (CPOL), when the transmission is initiated (CS is pulled low) and the sampling edge, called (CPHA), is as shown in the following table:

Mode	Polarity (CPOL)	Phase (CPHA)
0		
3		

SPI interface can have only one Master and can have one or multiple Slaves. Figure 8 shows the SPI connection between the Master and the Slave.

8.2.2 CS Chip Select signal

The CS Chip Select signal from the Master is used to select the Slave. This is an active low signal and is pulled high to disconnect the Slave from the SPI bus. When multiple Slaves are used, an individual CS Chip Select signal for each Slave is required from the Master. In Lika encoders the CS Chip Select signal is always an active low signal.

8.2.3 MOSI and MISO signals

MOSI and MISO are the data lines. MOSI transmits data from the Master to the Slave and MISO transmits data from the Slave to the Master. Data is sent byte by byte in packages of 8 bits and with the msb (most significant bit) first. Each data transmission starts when a 1-byte opcode is sent by the SPI Master (see the "8.2.5 Command byte" section on page 35).

8.2.4 Data Transmission

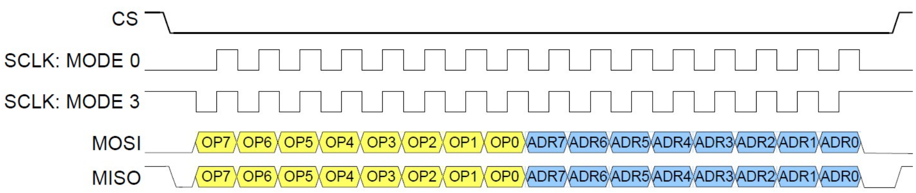


Figure 9 - SPI transmission SPI Mode 0 and 3, using opcode Read REGISTER (single) as an example

Here follows a description of a typical sequence of an SPI data transmission, assuming that the **Read REGISTER (single) command** is transmitted (see Figure 9).

1. To begin SPI communication, the Master initializes the transmission: it sends the SCLK clock signal and selects the Slave by enabling the CS Chip Select signal. CS Chip Select is an active low signal; hence, the Master must send a logic 0 on this signal to select the Slave.

2. The encoder changes its communication level from MOSI to MISO. SPI is a full-duplex interface; both Master and Slave can send data at the same time via the MOSI and MISO lines respectively. During SPI communication, the data is simultaneously transmitted (shifted out serially onto the MOSI bus) and received (the data on the bus -MISO- is sampled or read in). The serial clock edge synchronizes the shifting and sampling of the data. As previously stated, data is transmitted in packages of 8 bits. The output data length must be a multiple of 8 bits.
3. Now the Master transmits the opcode OP and the address ADR via MOSI.
4. The encoder immediately outputs OP and ADR via MISO.
5. The encoder transmits the requested data according to the address.
6. The Master ends the command with a rising edge at CS.
7. Finally the encoder switches its MISO output to 1.

8.2.5 Command byte

Each communication frame starts with a command byte. It consists of an operating code which specifies the type of operation and an 8 bit address.
The available SPI codes are:

Code	Description
0xA6	**SDAD transmission command** (sensor data SD)
0xF5	**SDAD status command** (no latch)
0x97	**Read REGISTER (single) command**
0xAD	**REGISTER status / data command**

SDAD transmission command

SMAR1 latches the absolute position on the first rising edge at SCLK, when CS is at zero (REQ/LATCH). Because SMAR1 can output the sensor data (SD) immediately, the Master can transmit the **SDAD transmission command** directly. The sensor data shift register (the size of which is 8 to 40 bits in multiples of 8) is switched and clocked out between MOSI and MISO.
If invalid data is sampled in the shift register, the ERROR bit is set in the SPI STATUS byte (see the table in the **REGISTER status / data command** on page 38) and the output data bytes are set to zero.

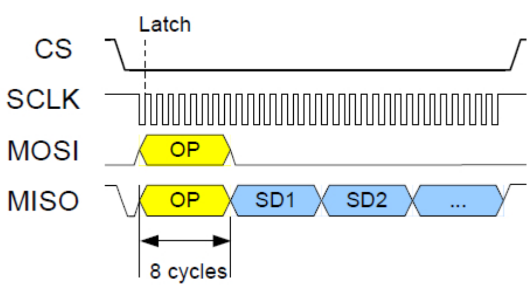


Figure 10 – SDAD transmission: read SD

SDAD status command

If the Master does not know the processing time of the connected Slaves, it can request sensor data using the **SDAD status command**. The command causes:

1. all Slaves are activated via PACTIVE to switch their SVALID register between MOSI and MISO;
2. the next request for sensor data started with the first rising edge at SCLK of the next SPI communication is ignored by the Slave.

The end of conversion is signalled by SVALID (SV). Using this command, the Master can poll to the end of conversion. The sensor data is read out via the **SDAD transmission command**.

SVALID (SV)	
Code	**Description**
0	Sensor data not valid
1	Sensor data valid

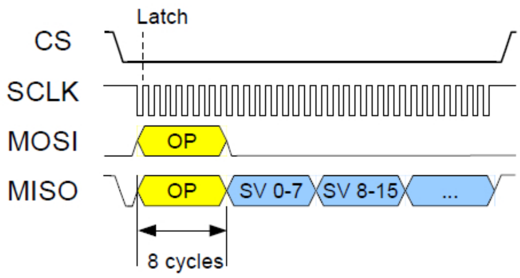


Figure 11 - SDAD status

Figure 12 shows the interaction of the two **SDAD status commands** and **SDAD transmission commands**. It is not necessary to start each sensor data communication with the **SDAD status command** (1). SMAR1 has no processing time and can therefore directly output valid sensor data. For this reason the command sequence can start with **SDAD transmission command** (2). Following this, the **REGISTER status / data command** should be executed to detect an unsuccessful SPI communication.

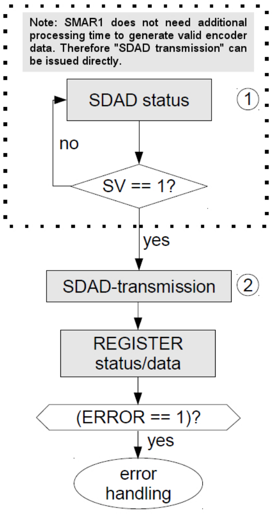


Figure 12 - Example sequence of the commands SDAD Status / SDAD transmission

Read REGISTER (single) command

This command enables register data to be read out from the Slave byte by byte. The Master transmits the **Read REGISTER (single) command** first and then the address ADR. The Slave immediately outputs the command and address at MISO.

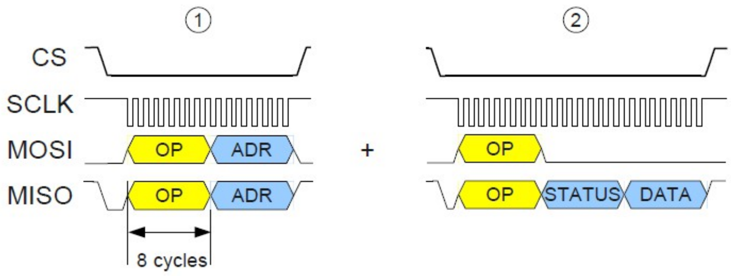


Figure 13 - Read REGISTER (single); set the read address (1) + command REGISTER status / data to read-out data (2)

Following this, using the **REGISTER status / data command** the Master can poll until the validity of the DATA following the SPI STATUS byte is signalled via SPI STATUS.

NOTE

To know the status of the encoder and whether there are active errors, you must read **registers 76 and 77**. For more information please refer to the "10.3 Status registers – SPI interface" section on page 44.

Write REGISTER (single) command

(not used at the moment)

This command enables data to be written to the Slave byte by byte.

The Master first transmits the **Write REGISTER (single) command** and then address ADR and the data (DATA). The Slave immediately outputs the command, address, and data at MISO.

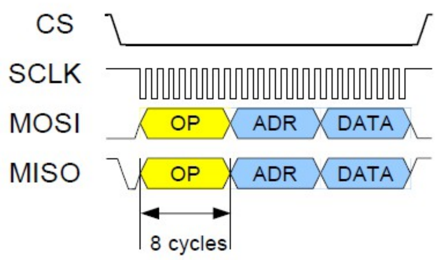


Figure 14 - Write REGISTER (single); set write address and data

Using the **REGISTER status / data command**, the Master can poll to the end of the register communication (signalled via the SPI STATUS byte).

REGISTER status / data command

The **REGISTER status / data command** can be used to request the status of the last register communication and/or the last data transmission. The SPI status byte contains the information summarized in the following table.

Bit	Name	Description of the status report
7	ERROR	Opcode not implemented, sensor data was invalid on readout
6 ... 4	Reserved	
3	DISMISS	Address rejected
2	FAIL	Data request has failed
1	BUSY	Slave is busy because of a previous request
0	VALID	DATA is valid

Logic level: 1 = true; logic level 0 = false

All SPI status bits are updated at each register access.

The exception to the rule is the ERROR bit; this bit indicates whether an error occurred during the last SPI communication with the Slave.

The Master transmits the **REGISTER status / data command**. The Slave immediately passes the opcode on to MISO. Then the Slave transmits the SPI STATUS byte and a DATA byte.

Following the **Read REGISTER (single) command** and the **Write REGISTER (single) command**, the validity of the DATA byte is signalled with the VALID status bit.
The requested data byte is sent back via DATA following the **Read REGISTER (single) command**. Following the **Write REGISTER (single) command**, the data to be written is repeated in the DATA byte. With all other opcodes, the DATA byte is not defined.
Figure 15 shows the interaction of the **Read REGISTER (single) command**, **Write REGISTER (single) command**, and **REGISTER status / data command**.

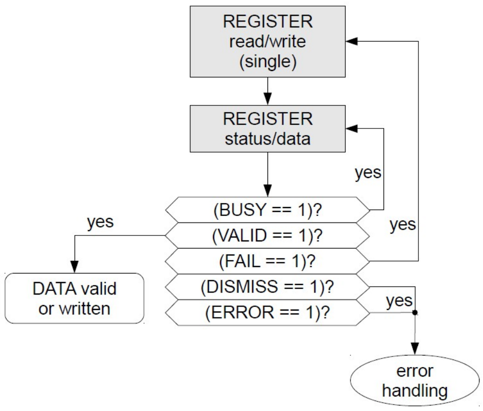
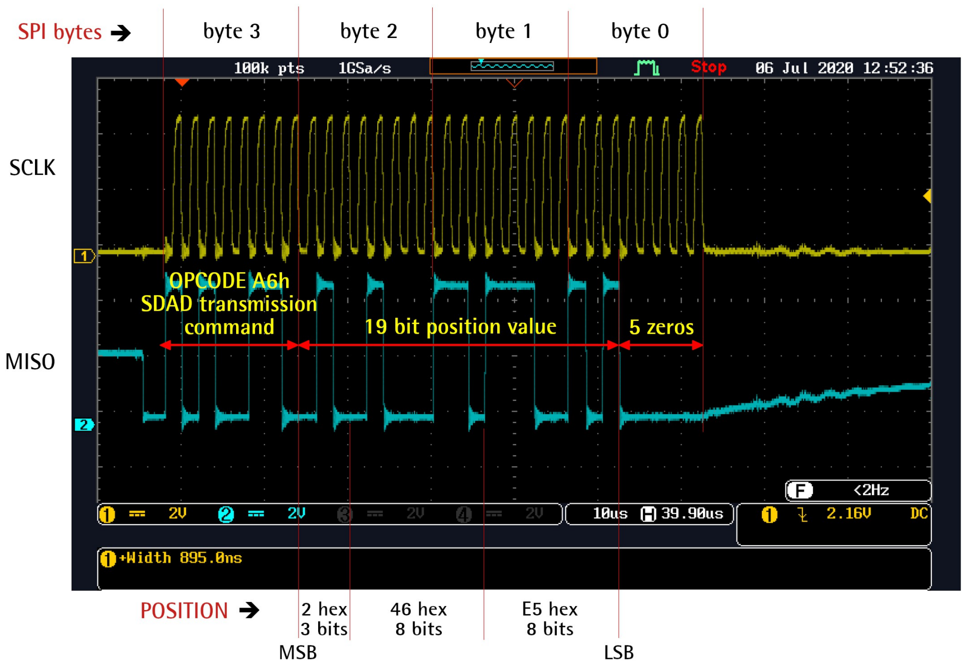


Figure 15 - Example sequence of commands REGISTER read/write and REGISTER status/data

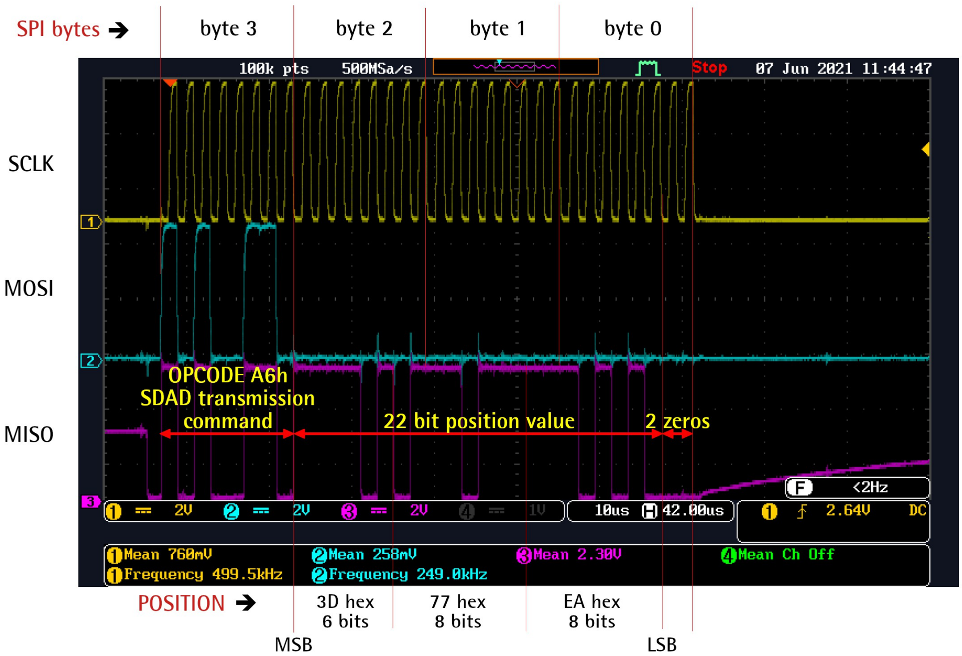
8.2.6 Reading the position value 149,221 dec

Here follows an example of reading the position value 149,221 dec = 2 46E5 hex = 0100100011011100101 bin in a 19 bit singleturn encoder. Send the OPCODE **SDAD transmission command** (see on page 35).



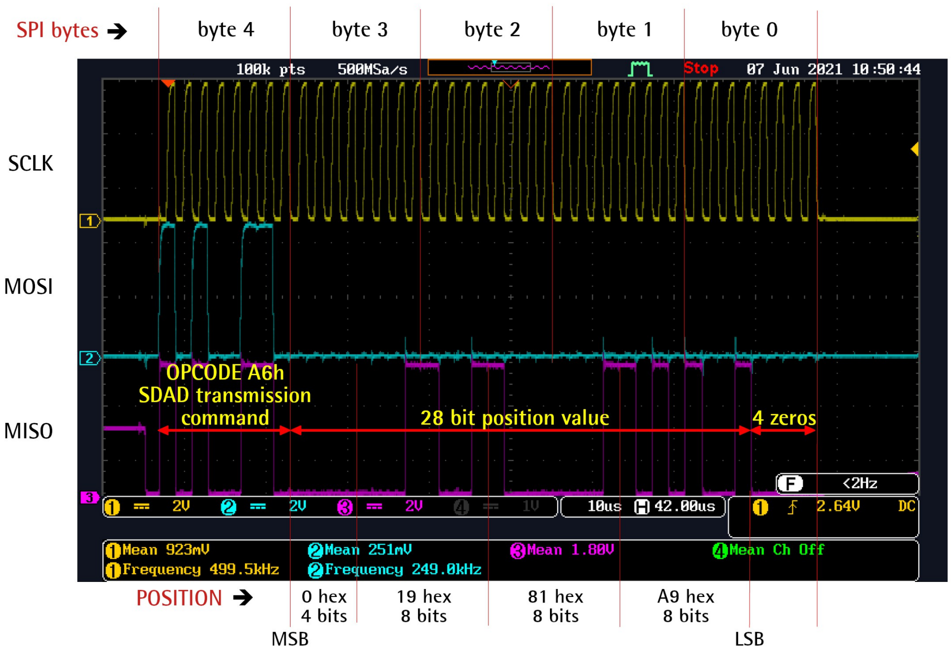
8.2.7 Reading the position value 4,028,394 dec

Here follows an example of reading the position value 4,028,394 dec = 3D 77EA hex = 0011110101110111111101010 bin in a 22 bit multiturn encoder (12 bit singleturn resolution + 1024 revolutions). Send the OPCODE **SDAD transmission command** (see on page 35).



8.2.8 Reading the position value 1,671,593 dec

Here follows an example of reading the position value 1,671,593 dec = 19 81A9 hex = 0000000110011000000110101001 bin in a 28 bit multiturn encoder (19 bit singleturn resolution + 512 revolutions). Send the OPCODE **SDAD transmission command** (see on page 35).

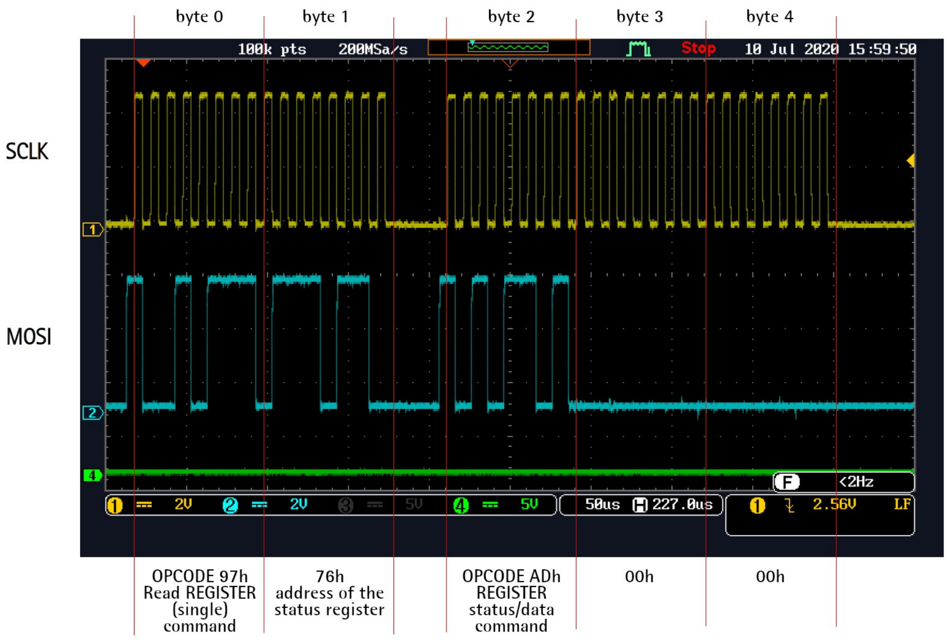


8.2.9 Reading the register 76 hex (Status 0)

Here follows an example of reading the register 76 hex (Status 0), see the "10.3 Status registers – SPI interface" section on page 44.

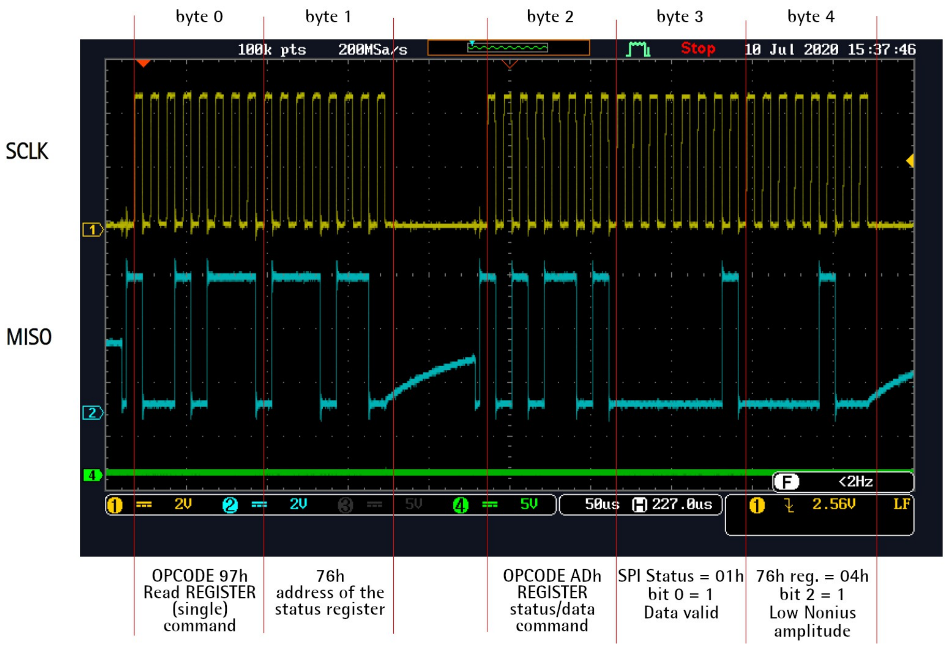
When you need to read a register you must carry out the following operations:

1. Send the OPCODE **Read REGISTER (single) command** (see on page 35) and then send the Address of the register to read;
2. execute another transaction and send the OPCODE **REGISTER status / data command**.

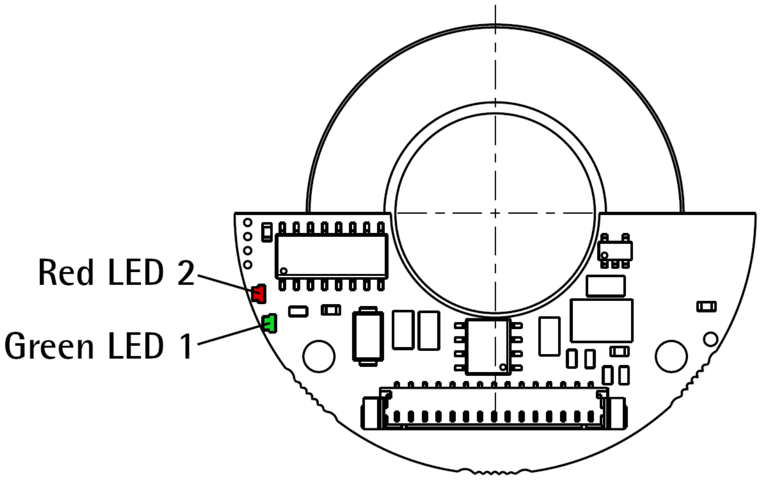


Two bytes are sent back: SPI_STATUS and DATA.

In the Figure below, the SPI Status has bit 0 = 1 (VALID, DATA is valid, see on page 38); and the Register 76h (Status 0) has 1 error (bit 2 = **Signal warning**, signal amplitude too low in the nonius track, see on page 44).



9 - Diagnostic LEDs



Two LEDs are installed in the sensor, they are designed to show visually the operating or fault status of the device, as explained in the following table. The operating or fault status of the device is also communicated through the error bit / status register, refer to the “6.4 Error bit” section on page 27 (SSI interface), to the “Error” section on page 30 (BiSS interface), and to the “REGISTER status / data command” section on page 38 (SPI interface).

POWER SUPPLY LED 1 (GREEN)	Description
OFF	The power supply is OFF
ON lit green	The power supply is ON

ERROR LED 2 (RED)	Description
OFF	The sensor is working properly, there are no active errors.
ON lit red	An error is active in the measuring system. For complete information on the available errors, please refer to the “10 – Warnings and errors” section on page 43.

10 – Warnings and errors

This section provides a comprehensive list of all warnings and errors, and then explains how to retrieve them.
Errors are signalled through the ERROR diagnostic LED as well as the error bit / status register and are available in all interfaces, refer to the "6.4 Error bit" section on page 27 (SSI interface), to the "Error" section on page 30 (BiSS interface), and to the "REGISTER status / data command" section on page 38 (SPI interface). Warnings are available in the BiSS interface only and signalled through the warning bit, refer to the "Warning" section on page 31.

10.1 Warnings

Here follows the list of the available warnings.

Signal warning	The signals are not proper or their amplitude is too high or too low. The ring is not read correctly. It may be due to one of the following reasons: the ring and/or the sensor are not mounted properly (see the "3 - Mounting instructions" section on page 12); the ring magnetic surface is damaged somewhere; the sensor is not working properly; this may cause invalid data to be transmitted.
Frequency warning	The ring is rotating too fast. Slow down the speed of the ring to tolerance limits.

10.2 Errors

Here follows the list of the available errors.

Startup error	• An EEprom communication error or a CRC error occurred. Switch the power off and then on again. If the error is still active, please contact Lika's After-Sales Service. • The signals are not proper or their amplitude is too low. The ring is not read correctly. It may be due to one of the following reasons: the ring and/or the sensor are not mounted properly (see the "3 - Mounting instructions" section on page 12); the ring magnetic surface is damaged somewhere; the sensor is not working properly; this may cause invalid data to be transmitted.
Command execution in progress	A command is still under execution. Please wait for the command to be executed before sending further commands.

Consistency error	The ring is not read correctly. It may be due to one of the following reasons: the ring and/or the sensor are not mounted properly (see the "3 - Mounting instructions" section on page 12); the ring magnetic surface is damaged somewhere; the sensor is not working properly; this may cause invalid data to be transmitted.

Communication error	Communication error. It may be due to the EEprom, it may be damaged; or it may be due to the I2C. Switch the power off and then on again. If the error is still active, please contact Lika's After-Sales Service.

Invalid checksum	An invalid checksum occurred in the internal RAM. Switch the power off and then on again. Try the command again. If the error is still active, please contact Lika's After-Sales Service.

10.3 Status registers – SPI interface

Status information can be read out via status bytes at addresses 76 and 77 in the SPI interface.

Register 76

Bit	Warning / Error
0	**Signal warning**, signal amplitude too low in the master track, see on page 43
1	**Signal warning**, signal amplitude too high in the master track, see on page 43
2	**Signal warning**, signal amplitude too low in the nonius track, see on page 43
3	**Signal warning**, signal amplitude too high in the nonius track, see on page 43
4	**Startup error**, see on page 43
5 … 7	Not used

Register 77

Bit	Warning / Error
0	**Command execution in progress**, see on page 43
1	**Frequency warning**, signal frequency of internal 12 bit converter too high, see on page 43
2	**Frequency warning**, signal frequency of AB0 converter too high, see on page 43

3	**Consistency error**, see on page 44
4 & 5	Not used
6	**Communication error**, see on page 44
7	**Invalid checksum**, see on page 44

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Document release	Release date	Description	HW	SW	Interface
1.0	12.09.2019	First issue	-	-	-
1.1	20.12.2019	New connection cable	-	-	-
1.2	03.04.2020	New mounting drawings, Y2 and GG1 versions removed	-	-	-
1.3	14.04.2020	Connection information updated	-	-	-
1.4	20.07.2020	SPI reading examples added	-	-	-
1.5	04.08.2020	Mounting requirements information updated	-	-	-
1.6	09.10.2020	Mounting requirements information updated (Figure 3)	-	-	-
1.7	09.06.2021	SPI interface information updated	-	-	-
1.8	25.02.2022	SSI interface information updated, minor amendments	-	-	-
1.9	23.02.2023	New product name for incremental version (SMIR1), new order code, minor amendments, general revision	-	-	-
1.10	17.04.2023	Product name of the incremental version turned back to SMAR1-L1, minor amendments	-	-	-

Dispose separately

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