BALLUFF

Interfaces for BML
Magnetically Coded Position Measuring System

Basic Information

english

www.balluff.com

1 Notes to the user

1.1 Validity

This manual describes electrical interfaces for the Balluff BML sensors and supplements the documentation for the sensor families.

The document describes the following interfaces:
- IO-Link
- SSI
- BiSS-C
- absolute Quadrature
- 1Vpp (sin/cos)
- RS422/HTL A/B
- G-interface (functionally safe position signal)

Not all interfaces are available on every sensor. The possible interfaces and their specific parameters (levels, timing etc.) are described in the respective user's guides.

The guide is intended for qualified technical personnel. Read this guide before installing and operating the linear encoder.

1.2 Symbols and conventions

Note, tip
This symbol indicates general Notes.

1.3 Abbreviations

1Vpp	Incremental sin/cos interface
BiSS	Bi-directional synchronous serial interface
CDM	Control Data Master
CDS	Control Data Slave
CLK	Clock
CRC	Cyclic redundancy check
Data	Serial data signal
EDS	Electronic Data Sheet
FMEA	Failure Mode and Effects Analysis
EW event	Errors/warnings are transferred in the serial data set.
PL	Performance Level
SIL	Safety Integrity Level
SSI	Synchronous Serial Interface
VH	Virtual reference run (Virtual Homing)

1.4 Terms used

Absolute position	Measured position within the coordinate system of the known physical position
Known physical position	Uniquely defined position in the system in which for example a reference sensor or a mechanical end position defines the coordinate system of the absolute measured position.
True absolute position	Actual absolute position within the system
Fine position	Interpolated position value of the sin/cos interface, e.g. in 1/1000 of a period
Rough location of	Quadrant of the sin/cos interface
Initial homing move	Very first reference move to a known physical position
Uncertainly generated absolute value	The absolute value may not be used without a plausibility check against the safe incremental signal in safety applications.
Magnitude	Calculated magnitude determined from the four sin/cos signals

2 Interfaces

2.1 IO-Link interface

> IODD and XML file via download on the Internet at **www.balluff.com** or email to **service@balluff.de**.

General

IO-Link integrates conventional and intelligent sensors and actuators in automation systems and is intended as a communication standard below classic field buses. Field-bus-independent transfer uses communication systems that are already available (field buses or Ethernet-based systems).

IO-Link devices, such as sensors and actuators, are connected to the controlling system using a point-to-point connection via a gateway, the IO-Link master. The IO-Link devices are connected using commercially available unshielded standard sensor cables.
Communication is based on a standard UART protocol with a 24-V pulse modulation in half-duplex operation. This allows classic three-conductor physics.

Protocol

With IO-Link communication, permanently defined frames are cyclically exchanged between the IO-Link master and the IO-Link device. In this protocol, both process and required data, such as parameters or diagnostic data, is transferred. The size and the type of the frame and cycle time used result from the combination of master and device features (see Device specification in the user's guide for the sensor).

Cycle time

The cycle time used (master cycle time) results from the minimum possible cycle time of the IO-Link device (min cycle time) and the minimum possible cycle time of the IO-Link master. When selecting the IO-Link master, please note that the larger value determines the cycle time used.

Protocol version 1.0 / 1.1

In protocol version 1.0, process data larger than 2 bytes was transferred spread over multiple cycles.
From protocol version 1.1, all available process data is transferred in one frame. Thus, the cycle time (master cycle time) is identical to the process data cycle.

> The Balluff BML sensors correspond to protocol version 1.1.
> Operating the IO-Link device on an IO-Link master with protocol version 1.0 results in longer transfer times (process data cycle ~ amount of process data x master cycle time).

Parameter management

A parameter manager that enables device parameters to be saved on the IO-Link master is defined in protocol version 1.1. When exchanging an IO-Link device, the parameter data of the previous IO-Link device can be taken over. The operation of this parameter manager is dependent on the IO-Link master and is explained in the corresponding description.

2 Interfaces (continued)

2.2 SSI interface

RS422 differential signal

> **i** If the sensor is supplied with voltage that is isolated from the processing electronics, the GND for this voltage must be connected to the GND of the processing electronics.

Suggested circuit for processing:

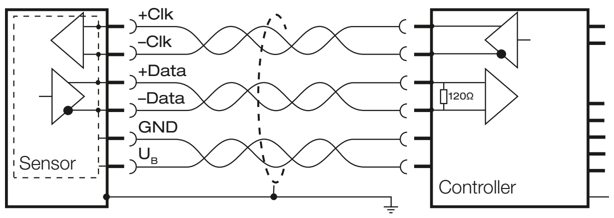


Fig. 2-1: Wiring example for a sensor with controller

> **i** The wires for Clk, Data and Power must be in twisted pairs (see Fig. 2-1).

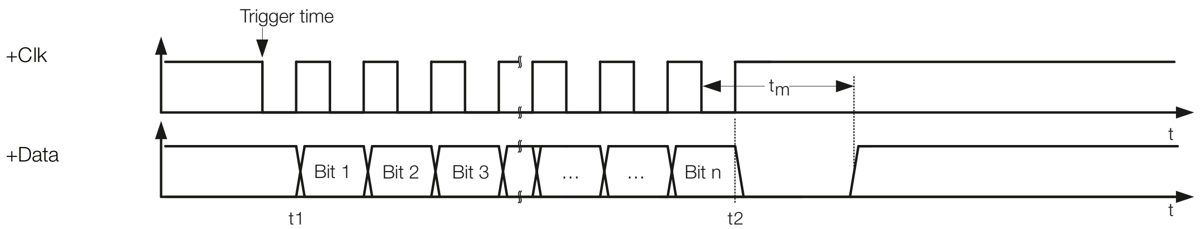
Clock pulses may only be sent when there is power to the measuring system.

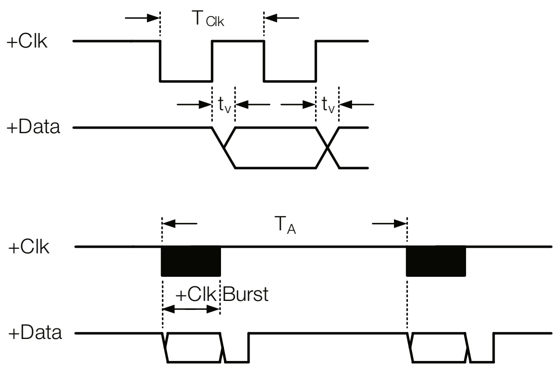
> **i** The data output of the BML must be loaded with 120 Ω, otherwise incorrect measurements may result.

2.2.1 Principle

SSI stands for Synchronous Serial Interface and describes a digital synchronous interface with a differential clock line and a differential data line.
With the first **falling** clock edge (trigger time), the data word to be output is buffered in the sensor head. Data output takes place with the first rising clock edge, i.e. the sensor supplies a bit to the data line for each rising clock edge. In doing so, the line capacities and delays of drivers t_v when querying the data bits must be taken into account in the controller.
The max. clock frequency f_{Clk} is dependent on the cable length. The t_m time, also called monoflop time, is started with the last falling edge and is output as the low level with the last rising edge. The data line remains at low until the t_m time has elapsed. Afterwards, the sensor is ready again to receive the next clock packet.

> **i** The meaning of the bits and relationship between maximum cable length and clock rate is described in the guide for the sensor.





T_{Clk} = $1/f_{Clk}$ SSI clock period, SSI clock frequency
T_A = $1/_A$ Sampling period, sampling rate
n Number of bits to be transmitted (requires n+1 clock impulses)
t_m = $2 \times T_{Clk}$ Time until the SSI interface is ready again
$t\backslash_v$ = 150 ns Transmission delay times (measured with a 1 m cable)

Fig. 2-2: Signals with SSI interface

Bit 1	Bit 2	…	Bit n-1	Bit n	Dec value
0	0		0	1	1
0	0		1	0	2
0	0		1	1	3

Tab. 2-1: Value of the sent bits for binary transmission

2 Interfaces (continued)

2.2.2 Faulty SSI query

Clocking too fast

> **i** This error is described in the guide for the sensor.

Underclocking

If there are too few clock edges, the current data level will be maintained for the time t_m after the last negative edge from +Clk. If, however, another positive edge occurs within the t_m time, the next bit will then be output. If the t_m time has expired, the +Data output goes high. The high level is maintained until the next clock burst.

Overclocking

If there are too many clock edges, the data output will switch to low after the correct number of cycles has been completed. With each additional negative edge of +Clk the t_m time is restarted. The +Data output switches back to high after the time t_m has elapsed.

Calculated resolution adjustment

Intentional over- and underclocking allows the calculated resolution of the sensor to be doubled or halved.

Example

Assume the sensor has a resolution of 1 µm and the number of bits is 25.

- The data bit for the 25th Clk has a value of 1 µm
- The data bit for the 24th Clk has a value of 2 µm
- The data bit for the 23rd Clk has a value of 4 µm
- etc.

If the controller only outputs 24 clock pulses, the sensor can only output 2-µm increments. To the controller it appears the sensor has a resolution of 2 µm. In other words for a travel distance of 1 mm the position does not change by 1000 increments, but rather by only 500 increments.

If the controller outputs too many clock pulses, the calculated resolution of the sensor is reduced.

- The data bit for the 25th Clk has a value of 1 µm
- The data bit for the 26th Clk is null and has a value of 1/2 µm
- The data bit for the 27th Clk is null and has a value of 1/4 µm
- etc.

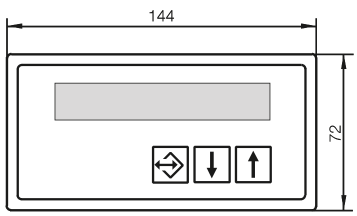
If the controller outputs 27 clock pulses, to the controller it appears the sensor has a resolution of 1/4 µm. When traveling over 1 mm the position changes by 4000 increments in 4-increment steps.
If a controller does not support the configurable number of bits, a different clock count can be used. To ensure correct processing of the measured value the resolution per bit must be adjusted.

2.2.3 Display/controller for SSI

The following display units are available for the SSI interface:

Digital display BDD-AM 10-1-SSD

Ordering code: BAE0069



Housing depth 110 mm

- SSI master interface (see Fig. 2-3)
- 7 1/2-digit display with algebraic sign

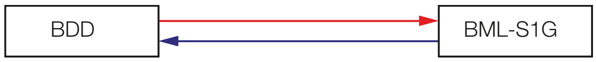
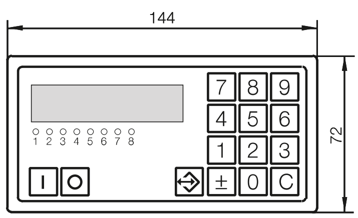


Fig. 2-3: Use as SSI master

CAM controller BDD-CC 08-1-SSD

Ordering code: BAE006F



Housing depth 110 mm

- SSI master (see Fig. 2-4) or slave interface (see Fig. 2-5)
- 8 outputs programmable
- 8 directional switching points possible

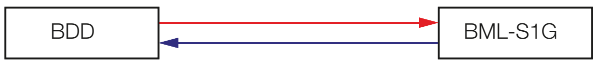


Fig. 2-4: Use as SSI master

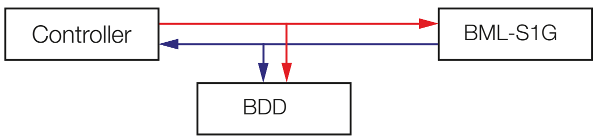


Fig. 2-5: Use as slave

2 Interfaces (continued)

2.3 BiSS C interface

BiSS INTERFACE

The XML file can be obtained at **www.balluff.com** or via email to **service@balluff.de**.

RS422 differential signal

If the sensor is supplied with voltage that is isolated from the processing electronics, the GND for this voltage must be connected to the GND of the processing electronics.

Suggested circuit for processing:

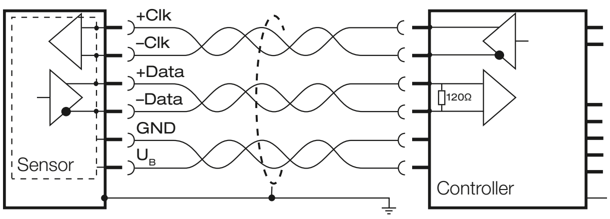


Fig. 2-6: Wiring example for a sensor with controller

The wires for Clk, Data and Power must be in twisted pairs (see Fig. 2-6).

Clock pulses may only be sent when there is power to the measuring system.

For further information, see: **www.biss-interface.com**.

The data output of the sensor must be loaded with 120 Ω, otherwise incorrect measurements may result.

With the BiSS C interface, both position data and register data can be transmitted bi-directionally. The register data is transmitted parallel to the position data and has no effect on the system's measuring behavior. The Balluff BiSS C sensor heads can be connected to the controller via a point-to-point connection.

Transmission is CRC-secured, i.e. the controller can check if the data was received correctly. If the transmission has failed, the data can be discarded and requested again.

Transmission (as shown in Fig. 2-7) offers the following possibilities:

- An error and a warning bit are also transmitted.
- Secure bi-directional data transmission is always available (register communication).
- Runtime compensation of the clock and data line is possible. This makes it possible to use larger cable lengths or higher data rates.

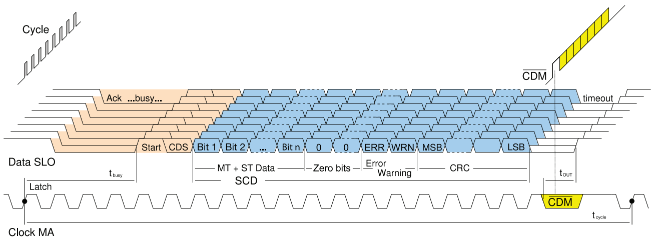


Fig. 2-7: Signal sequence for the BiSS C interface

- With the first **rising** edge (trigger time), the controller signals that it is requesting a value from the sensor head. The measurement value valid at this point is included in the data transmission later on.
- The sensor confirms the data request with the second rising edge of the clock by setting low on the data line.
- The time difference between the second rising edge of the clock and the first low of the sensor data line corresponds to the runtime of both signals. It appears with all further frame edges and can thus be compensated for in the controller. This makes it possible to use much longer cables or higher data rates than with SSI interfaces.
  Example: Data with a clock rate of 1 MHz can be transmitted for example up to 400 m. Only around 20 m would be possible without runtime compensation.
- All further bits that the sensor transfers are output in the sensor at the next rising edge.
- The sensor prepares the data during t_{busy}. When preparation is complete, the sensor sets the data signal to high (start bit). Beginning with the CDS the sensor then send one bit of data with each clock cycle. The data bit is either the echo of the CDM bit which was received in the last data set or one bit of the requested register data.
- Then the data from Bit1 to Bitn are sent.
- An error bit and warning bit as well as the CRC follow.
- Register communication:
  A bit can be transmitted by the controller to the sensor with each frame. To do this, the controller's clock signal is either set to high or low during t_m time (timeout = $2 \times t_{Clk}$). The sensor recognizes it as a high or low bit (CDM) and mirrors it in the CDS bit in the next frame. As a result, the controller can detect if the bit was recognized correctly (secure transmission).

2 Interfaces (continued)

– By transmitting one bit per frame, various addresses in the sensor can be read and written using several frames. Further information on errors or warnings are also available there. Customer data can also be saved and read (see Fig. 2-7).

2.3.1 CRC

To ensure the integrity of the data, a cyclic redundancy check (abbreviated CRC) is used in the controller. Here, a check value is calculated for the transmitted data in both the sensor and controller and then compared. If both values are identical, the data has been transmitted correctly. If they are different, the data has been transmitted incorrectly and the position value must be requested again.

The controller is parameterized as follows:

CRC: 6 bits (transferred inverted)

The counter polynomial for CRC determination is 0x43 (hex), 67 (dec) or 1000011 (bin).

Uni-directional BiSS C

Only the data is transmitted from the measuring system to the controller. No additional information can be or is transmitted (such as register communication with BiSS C).

Uni-directional signal position/logics for BiSS C:
The time sequence of the individual bits is shown in Fig. 2-8.
CDS/CDM is always high, then come bits 1 to n. Then an error and a warning bit are transmitted. The error and warning bit in the data set is active low. If no error or warning is present, both bits are high.

> **i** The meaning/value of the bits is shown in Tab. 2-1 on page 6.

Bi-directional BiSS C

With the BiSS C interface, as with the SSI interface, errors and warnings (EW events) are transferred in the serial data set. Additionally, the type of event can also be queried via register communication.
The error and warning bits are, as with uni-directional interfaces, transferred in the serial data stream after the position data and before the CRC. In Fig. 2-7 the timing is shown. The error and warning bit in the data set is transferred as active low. If no error or warning is present, both bits are high.

Error byte, warning byte:
Using the register data, the controller can read the exact error or warning causes. The error byte is located at the BiSS register address 0x48 and the warning byte at BiSS register address 0x49. There, different error and warning causes are coded bit by bit.

> **i** The meaning of the error and warning bits is described in the user's guide for the sensor.

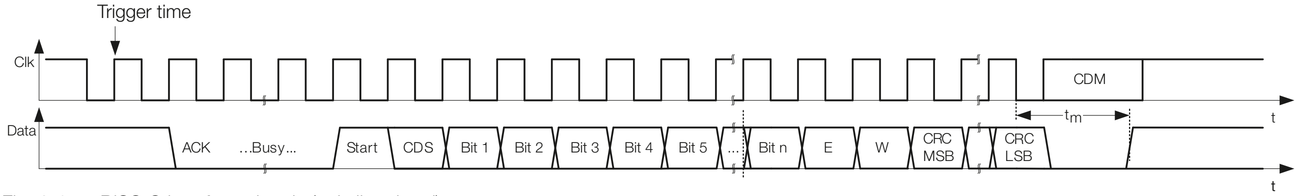


Fig. 2-8: BiSS C interface signals (uni-directional)

2 Interfaces (continued)

2.3.2 EDS

EDS, electronic data sheet, user area:

This BiSS C function allows the customer to permanently store and read out, byte by byte, any user-specific data in the EEPROM user area of the sensor via register communication.

The entire BiSS address space is divided into three areas:

- **Hidden**
  The user has no access.
- **Read Only** (EDS area)
  This area is read-only.
- **Read/Write** (user area)
  Here a certain number of bytes are available in banks of 64 bytes each (see user's guide for sensor). Mechanical assembly data for the sensor head, the assembly date, order designation for the sensor, etc. can be stored here.

The BiSS register address space (0x00…0x7F) is divided into two areas:

1. A **fixed area** which is always accessible in write and read mode (0x40 to 0x7F). This area can be used to select the bank that is to be edited. The following information can be read out:
   - Is an error or warning present?
   - Which error or warning is present?
   - At which bank is the electronic data sheet located?
   - Which bank has been selected from the switchable bank area?

2. A **selectable bank area** (0x00 to 0x3F) that displays different EEPROM areas depending on the selected bank. Depending on the bank, there may be no access, or “read only” or “read and write” access. The selected bank is entered at address 0x40. In the register address area 0x00 to 0x3F the corresponding bank is displayed. Fig. 2-9 shows the principle of relationships.

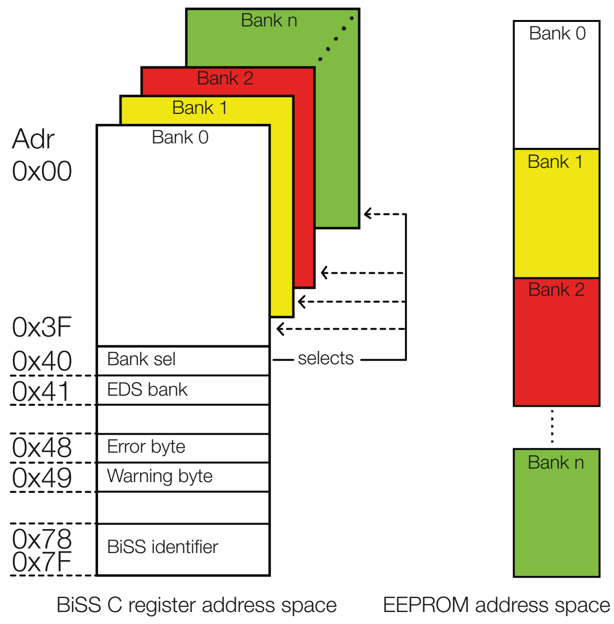


Fig. 2-9: BiSS C register address space

2 Interfaces (continued)

To read and write the user area, the configuration must first be read out from the EDS:
At BiSS C register address 0x41, the EDS bank is read out. The value from address 41 is then entered in register address 40 (bank selection). Afterwards, the following information is available:

– Address 0x00 the EDS version,
– Address 0x01 the number of EDS banks,
– Address 0x02 the beginning of the user area bank
– Address 0x03 the last user area bank.

In the user area, any data can be read and written. This data is stored permanently in the EEPROM. The user area can be used freely and data can be stored freely on the various banks: ASCII or binary-coded, plain text or encrypted, with or without CRC protection.

After a user area bank is entered at the address 0x40, any data in address space 0x00...0x3F can be read and written. With a different user area bank, other data can be written and read at the same addresses 0x00...0x3F without overwriting the data from the other banks. The data stored in the user area are always available, even after the system has been switched off and back on.

If other banks outside the user area are to be written to, an error message occurs.

For the following example, this syntax is used:

n	= [0x41]	Writing of n with the contents of address 41 (hex)
[0x40]	= 7	Writing of value 7 to the address 0x40 (hex)

Example for writing and reading three bytes in two user banks:

Reading out of the EDS
(reading of the definition of the user area)

n	= [0x41]	(EDS begins at bank n, here e.g. 1)
[0x40]	= n	(EDS bank is selected)
num	= [0x01]	(Number of EDS banks is read, e.g. 8)
User_beg	= [0x02]	(Beginning of the user area is read, e.g. 0x09)
User_last	= [0x03]	(Last user area bank is read, e.g. 0x0F)

Writing of the user area

[0x40]	= User_beg	(Select first user area bank, here 0x09)
[0x00]	= 0x11	(Enter any value in the first address of the first bank)
[0x3F]	= 0x1F	(Enter any value in the last address of the first bank)
…		
[0x40]	= User_beg+1	(Select second user area bank)
[0x00]	= 0x21	(Enter any value in the first address of the second bank)
…		

Optional Power off/on

Reading the written user area

[0x40]	= User_beg	(Select first user area bank)
n	= [0x00]	(n changes to 0x11, above value)
…		
[0x40]	= User_beg+1	(Select second user area bank)
n	= [0x00]	(n changes to 0x21, above value)
…		

i The data format and meaning of the individual bits is defined via the XML file, using the BiSS identifier. The BiSS identifier is described in the guide for the sensor.
Download this XML file from **www.balluff.com** or request it via e-mail to **service@balluff.de**.

2.4 Absolute quadrature interface

If the sensor is supplied with voltage that is isolated from the processing electronics, the GND for this voltage must be connected to the GND of the processing electronics.

The absolute quadrature interface uses the incremental digital A/B interface with Z-signal to send the absolute position when power is turned on. This gives a conventional incremental controller absolute functionality. No changes to the controller are necessary. No homing move is necessary and the absolute position is always available.

The absolute quadrature interface is compatible with the digital incremental A/B/Z interface). The user must select the desired resolution and minimum edge separation (see Tab. 2-2 on page 20) which is appropriate for the controller. This will give the maximum travel speed or rpm's for rotary applications. The relationship can be seen in the respective tables in the sensor user's guide. Tab. 2-2 on page 20 shows and example.

The sensor evaluates the signals as per Fig. 2-23 on page 19 and determines from that the s_AB position.

Switch-on behavior

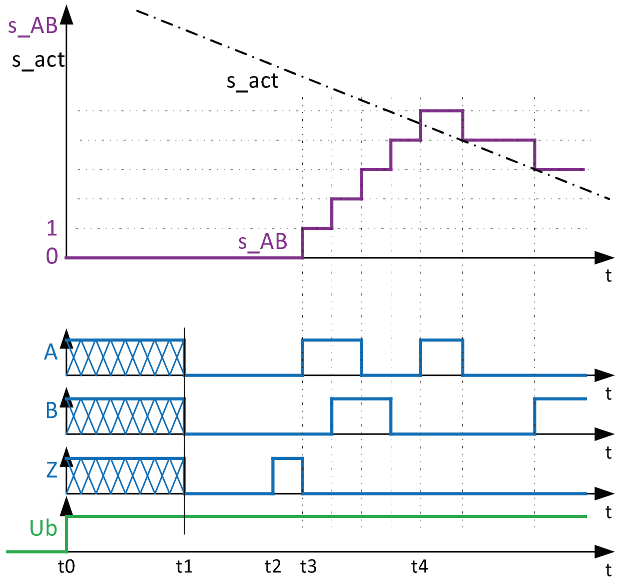


Fig. 2-10: Switch-on behavior

The exact timing at switch-on is described in Fig. 2-10: The sensor carries out a move corresponding to s_act. When power is turned on at time t0 all outputs are high impedance. At time t1, after the switch-on delay, the outputs are low impedance and the start delay $t_{VHstart\_delay}$ begins. It lasts until time t2. Now the virtual homing move VH begins. A Z-pulse is output between t2 and t3. The controller must use this to set its internal position counter to zero. Beginning with t3 the measuring system generates A/B increments until the incremental position s_AB has reached the physical position of the sensor head s_act, at time t4. From this point on the controller knows the physical position. Between t2 and t4 all edges are output with the minimum edge separation. Then the measuring system outputs *normal* increments which follow the physical movement s_act.

The time for VH (t_{VH}) is normally several milliseconds and is determined as follows:

$$t_{VH}\,[\mu s] = \frac{\text{Measuring length } [\mu m] \times \text{minimum edge separation } [\mu s]}{\text{Resolution } [\mu m/\text{Inc}]}$$

Edge separation and resolution are defined in the user's guide for the sensor.

Up to time t4 no controlled movement is permitted.
The time duration can be reduced by running the function *Preset*.
Each time the null point is crossed a Z-pulse is output.

2 Interfaces (continued)

Optional triggering of VH by an input

Optionally (see sensor user's guide) the differential input VH_{Req} can be used to trigger a virtual homing move. This requires that this input be high for t_{VH}. In Fig. 2-11 the timing is shown: Up to time t2 the s_AB position follows the physical position s_act with an offset. The offset is undefined as long as no Z-pulse has been sent. At time t0 the input VH_{Req} goes high. Once at time t1 the time t_{VH} has expired, the virtual homing move begins after $t_{VHstart\_delay}$ at time t2 with the same timing as shown in Fig. 2-11.

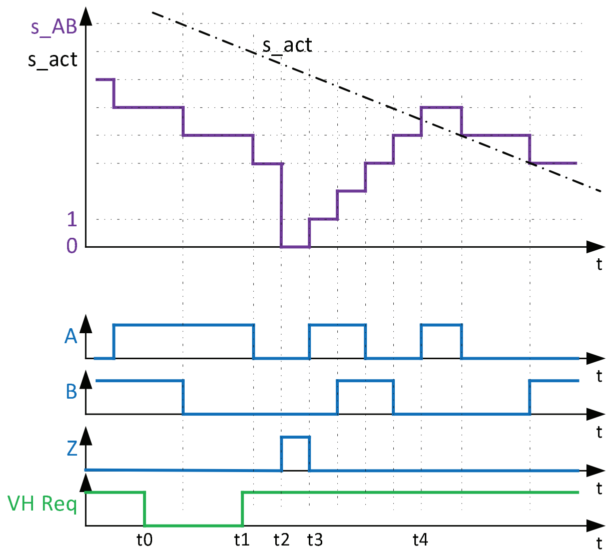


Fig. 2-11: Using input VH_{Req}

When the sensor is turned on, increments for the virtual homing move VH are output (see Fig. 2-10 on page 12). These increments are also output each time VH_{Req} (see Fig. 2-11) is requested.

Busy Signal instead of Z-Signal

As another option (see user's guide for sensor) a Busy signal can be output instead of the Z-signal. This tells the controller at which point the virtual homing move has been completed. The timing is shown in Fig. 2-12. The virtual homing move takes the time shown in Fig. 2-11 from t2 to t4.
Each time the zero position is crossed a new VH Busy signal is output.

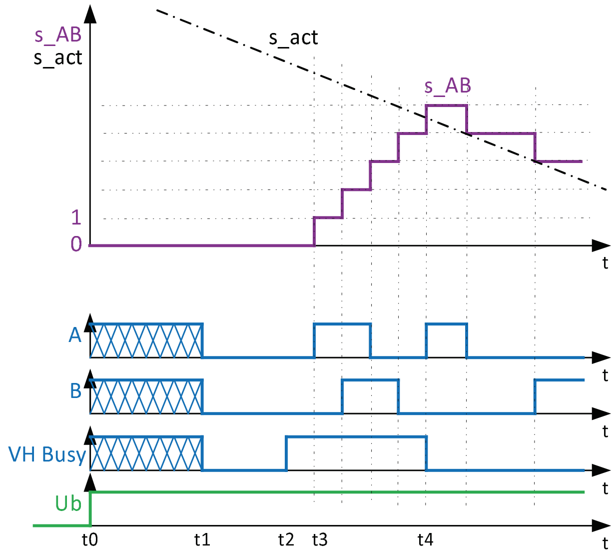


Fig. 2-12: "VHBusy" mode

Error response in tri-state

When the sensor detects an error it sets its output to high impedance. The controller can interpret this state as a cable break.
Once the error is no longer present the sensor behaves similarly to a switch-on. The timing is shown in Fig. 2-10 or Fig. 2-12. The error condition ends at time t1. An error will occur especially when moving out of the tape. Entering the tape corrects the error. There is no virtual homing move.

Reasons for a virtual homing move

VH (t2 to t4 in Fig. 2-10…Fig. 2-12) is carried out under the following conditions:

- After switch-on
- When the sensor resumes its normal operating state after an error
- When there is a request by the input VH_{Req}
- After performing the *Preset* function

2 Interfaces (continued)

2.5 1Vpp-(sin/cos) interface

> **i** If the 1Vpp signal is used together with the IO-Link interface, high common mode portions can be coupled using the IO-Link signals. These must be compensated by the processing circuit.

> **i** For correct function, the sine signal +A (+sin) – (–A (–sin)) and the cosine signal +B (+cos) – (–B (–cos)) must be evaluated depending on the direction.

> **i** If the sensor is supplied with voltage that is isolated from the processing electronics, the GND for this voltage must be connected to the GND of the processing electronics.

In the case of the analog sine and cosine signals +A (+sin), –A (–sin), +B (+cos) and –B (–cos) the controller evaluates the difference between the signal amplitudes:

A (sin) = +A (+sin) – (–A (–sin))
B (cos) = –B (cos) – (–B (–cos))
Z = +Z – (–Z)

Then the controller interpolates (e.g. using a factor of 1000) from the signals the exact position within a period (Fig. 2-13). This interpolated value is called the fine position. For a movement over several periods, the controller also counts the number of periods.

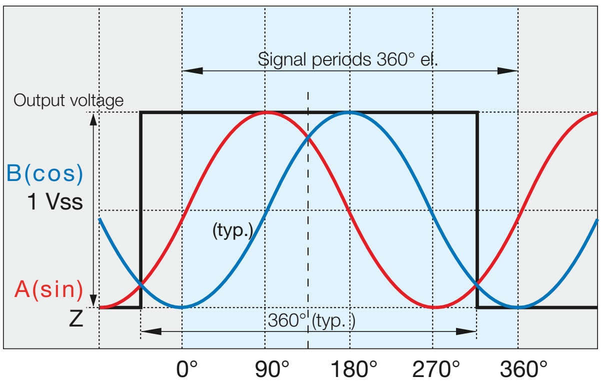


Fig. 2-13: Signals of the sine and cosine sensor, forward movement corresponds to increasing angle

The sensor sends the measurand as an analog sine-cosine differential signal with an amplitude of approx. 1 V_{pp} (peak-peak, 0.6…1.2 V). The period length is described in the sensor user's guide. When the sensor is outside the specified working range the voltage is reduced. The Z-pulse is not present in every sensor. It is described in the sensor user's manual.

In Fig. 2-14 a circuit example for processing using an operational amplifier is sketched. The signals +B (+cos) – (–B (–cos)) and ((+Z) – (–Z)) are evaluated correspondingly.

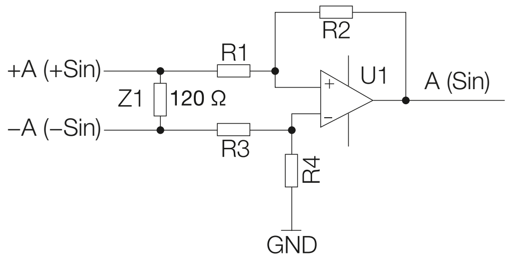


Fig. 2-14: Circuit example for follower circuit with analog output +A (+sin) – (–A (–sin))

2 Interfaces (continued)

2.6 G-interface (functionally safe position signal)

Position processing for the G-interface must be performed as for the 1Vpp-(sin/cos) interface.

2.6.1 General information

BML sensors with the G-interface (BML…) may be used in safety applications up to Safety Integrity Level 2 (SIL 2) per EN 61800-5-2 / EN 62061 / IEC 61508 and Performance Level d (PL d) per EN ISO 13849-1.

Sensors from series *BML with G-interface* provide the safety function *safe incremental value* . Here safe processing and transmission of the incremental rough position information of the measuring system is implemented via the analog sine/cosine interface. For safety applications which use the function *safe incremental value* only the rough position obtained from the quadrant detection of A and B may be used.

Some sensors from series *BML with G-interface* also provide the safety function *safe absolute value*. Here the absolute position value is generated and transmitted without safety. However a higher level plausibility check is made between the safe relative rough position information and a safe absolute value with the accuracy of the relative rough position information (see section 2.6.3 on page 16). The other sensor interfaces (BiSS, SSI, IO-Link, RS422, HTL…) may not be used alone in safety applications!

For safe operation the sensor must be used in a safe overall application. The user must consider the entire safety chain of the safety function (e.g. use of a safety controller) to determine the achieved SIL and PL.

Several Balluff BML sensors with G-interface are available which are listed in the document *BML-SIL-2 Sensors (Doc No. 934186).*

> ℹ The document *BML-SIL-2 Sensors (Doc No. 934186)* can be downloaded from the Internet at **www.balluff.com** or requested by email to **service@balluff.de**.

> ℹ If the sensor is supplied with voltage that is isolated from the processing electronics, the GND for this voltage must be connected to the GND of the processing electronics.

In addition to these instructions, refer also to the instructions from the respective user's guide.

2.6.2 Processing the safety incremental G-interface

From the four signals +A (+sin), –A (–sin), +B (+cos), –B (–cos) the differential signals A and B are formed as follows:

$$A = +A\ (+\sin) - (-A\ (-\sin))$$

$$B = +B(+\cos) - (-B\ (-\cos))$$

For safety applications which use the function *safe incremental value* only the rough position obtained from the quadrant detection of A and B may be used. The trigger levels for quadrature detection may be no higher than ±100 mV.

The safety controller must perform the error detection by determining and monitoring the magnitude (Z) of the two differential signals using the following algorithm:

$$Z = \sqrt{(A^2 + B^2)}$$

The magnitude Z must be determined with a frequency of at least 500 Hz. The magnitude Z must be monitored for the limits Z_u = 0.25 V and Z_o = 0.675 V. If these limits are exceeded or undershot, a safe state of the overall system must be initiated within the process safety time.

An error occurring in the sensor can not be detected sooner than after a movement of one period using magnitude monitoring.

The evaluation circuit must be dimensioned such that the magnitude at maximum travel speed (surface speed) v_{max} and the corresponding period length p of the system can be determined.
The maximum frequency of the A and B signals can be determined as follows:

$$f_{max} = v_{max} / p$$

The maximum frequency for quadrature determination is calculated as follows:

$$f_{max} = 4 \times v_{max}/p$$

For safety processing only the quadrants of the sin/cos-signals may be used. Interpolation of the sin/cos signals is not permitted for the safe path. Sin/cos signals (fine position) may however be used for controlling drives outside of a safety function.

2 Interfaces (continued)

2.6.3 Processing *safe absolute value* with a G-interface

The unsafely generated absolute position (BiSS C, SSI, IO-Link…) for the serial interface can be processed as a safe absolute value together with the safe incremental G-interface.

The following requirements must be met:

– Before using the safety function *safe absolute value* an initial homing move to a known physical position must be made at the first startup of the measuring system in order to detect the true absolute position.
– When using the safety function *safe absolute value* the measured absolute position values must be continually compared with the incremental information provided by the sensor. At any deviation between relative position and absolute position the absolute value must be presumed to be faulty and may not be used in any safety function. The safe incremental signal can in this case still be considered as non-faulty. To be able to consider the absolute signal as not faulty again, the initial homing move must be repeated.
– When using the safety function *safe absolute value* the absolute position may be safely processed at best with the accuracy of the quadrants of the sine/cosine signal, i.e. to ¼ of a period of the sine/cosine signal.

After cycling power there are two ways to detect an error in the non-safe absolute value:

Possibility 1

The user must ensure that the system when turned off does not experience a position change and must ensure correct implementation of this requirement through suitable means of fault prevention (e.g. performing an FMEA). In addition, the last measured absolute position value must be persistently stored when the measuring system is turned off. When the measuring system is turned on again the current value of the absolute position value must be measured and compared with the previously stored value. At any deviation between stored position and the new value must be presumed to be potentially faulty and may not be used in any safety function. The safe incremental signal can in this case still be considered as non-faulty.

To be able to consider the absolute signal as not faulty again, the initial homing move must be repeated.

Possibility 2

The user must ensure that the system when turned off does not experience a position change of greater than ± ¼ of a period (corresponds to ±1 quadrant) and must ensure correct implementation of this requirement through suitable means of fault prevention (e.g. performing an FMEA). In addition, at first startup of the system the user must safely store the location of the quadrant change of the safe incremental signal relative to the absolute signal for both travel directions.

When the measuring system is turned on again the current value of the absolute position value must be measured and compared with the safe incremental signal using the initially determined location of the quadrant change. The value of the safe absolute signal must lie in the same quadrant as measured using the safe incremental signal. At any deviation of the detected quadrant between incremental position and absolute signal the absolute value must be presumed to be potentially faulty and may not be used in any safety function. The safe incremental signal can in this case still be considered as non-faulty.

To be able to consider the absolute signal as not faulty again, the initial homing move must be repeated.

2.6.4 Safety requirements for electrical connection

The sensor must be powered by a PELV power supply. The differential signals A (between +A (+sin) and (–A (–sin)) and B (between +B (+cos) and –B (–cos)) must be loaded each with 120 Ω ±10 %.

2 Interfaces (continued)

2.6.5 Use

Installation

Ensure that the sensor head and tape are firmly attached over the entire service life under the actual ambient conditions. Correct layout and measures for fault prevention can be achieved for example by performing an FMEA. Notify installation and service personnel accordingly.

Startup

At initial startup the measuring system must first be moved without the motor and the plausibility of the measuring system checked (e.g. does the measured travel of 1 m actually correspond to a travel of 1 m?). This requires the entire travel distance to be covered.

In the second step the entire travel distance is covered using the motor. There should be no anomalies in the movement (great acceleration at a particular position or large noise at a particular position). If the behavior is not plausible, the position value must be presumed to be faulty.

Operation

The *Proof Test Interval* can be found in the sensor user's guide.

Decommissioning

When decomissioning the BML ensure that the safety function remains assured.

Fault behavior

When hazardous events occur in safety applications always contact the service department of the manufacturer!

2 Interfaces (continued)

Selecting safety functions

In the following some safety functions are listed according to EN 61800-5-2 which can be used to use BML sensors with the G-interface.

To implement the safety function the sensor must be used in a safe overall application. Here the user must take into consideration the entire safety chain of the safety function (e.g. use of a safety controller with appropriate safety program).

a) Safe operating stop (Safe operating stop, SOS)

After reaching a stop at time t1 the drive is held in position in a controlled manner.

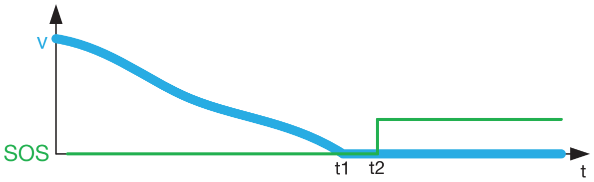


Fig. 2-15: Distance-time diagram for *safe operating stop*

b) Safe stop 1 (Safe stop 1, SS1)

With the trigger at time t1, e.g. E-Stop, the drive is rapidly stopped. At time t2 the drive is made torque- and force-free.

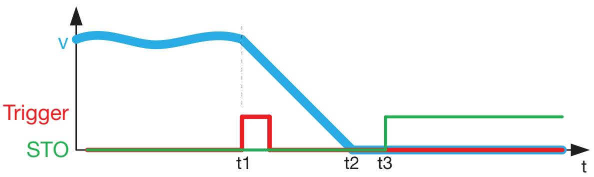


Fig. 2-16: Distance-time diagram for *safe stop 1*

c) Safe stop 2 (Safe stop 2, SS2)

With the trigger at time t1, e.g. E-Stop, the drive is rapidly stopped. The drive is then brought to the position.

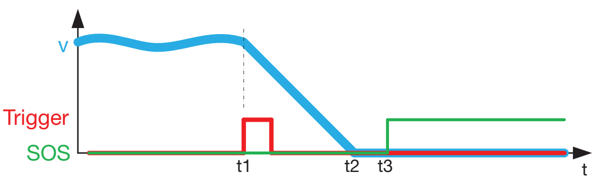


Fig. 2-17: Distance-time diagram for *safe stop 2*

d) Safely-limited speed (Safely-limited speed, SLS)

Monitors whether the drive is below a certain rpm or speed. This is the case in Fig. 2-18 starting at t1.

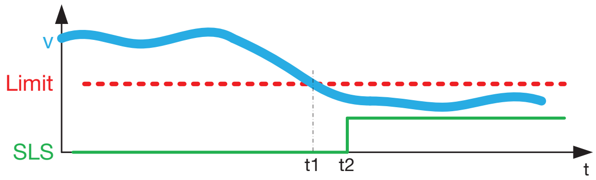


Fig. 2-18: Distance-time diagram for *safely-limited speed*

e) Safe speed monitor (Safe speed monitor, SSM)

A signal is generated when the rpm/speed of the drive is below a certain limit. In Fig. 2-19 this is true from t1 to t2 and from t3 to t4.

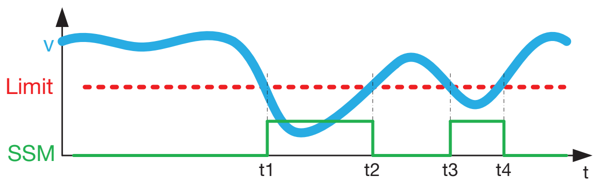


Fig. 2-19: Distance-time diagram for *safe speed monitor*

f) Safe direction (Safe direction, SDI)

The movement direction for the drive is monitored.

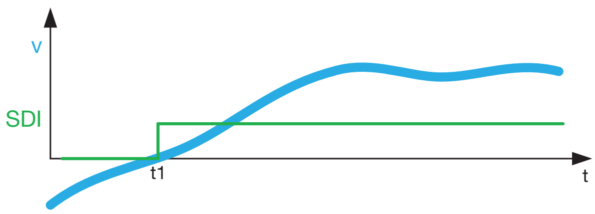


Fig. 2-20: Distance-time diagram for *safe direction*

g) Safely-limited position (Safely-limited position, SLP)

Monitors whether the drive leaves a defined travel range. This is the case in Fig. 2-21 between t1 and t2.

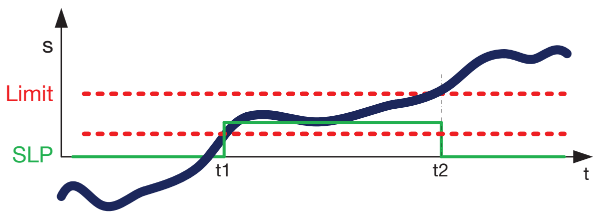


Fig. 2-21: Distance-time diagram for *safely-limited position*

2 Interfaces (continued)

2.7 Digital RS422/HT L-A/B/Z interface

2.7.1 Digital incremental measuring system

The sensor transfers the measurement as a differential voltage signal (RS422) or as an operational voltage (HTL) to the controller (depending on the variant). The edge separation A/B corresponds to the resolution of the sensor head.

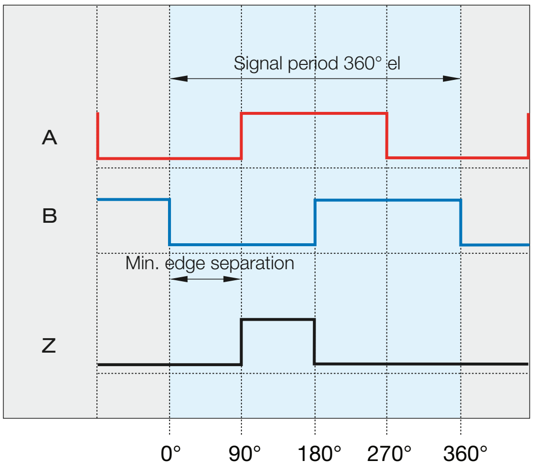


Fig. 2-22: Digital output signals for forward movement

The minimum possible distance between two edges, or also the minimum width of the Z-signal, is the minimum edge separation which must be defined when ordering the sensor. The processing controller must be able to detect this edge separation.

Every edge change from A or B means a position change of 1 increment. In Fig. 2-12 all possible conditions are shown. For each edge change the *Increment* line shows whether it is a positive or negative increment.
The line *Counter state* is the resulting counter state, beginning with 40. The direction of motion is shown in the *Motion direction* line, also indicating forward or reverse.
Counting just one signal is not sufficient for position determination.
The controller knows the precise increment position at all times, without having to periodically query the sensor (real-time capability).

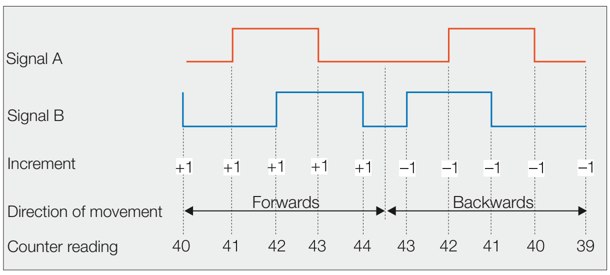


Fig. 2-23: BML output signals with period counter

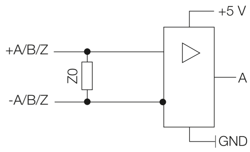


Fig. 2-24: Circuitry of subsequent electronics (RS422)

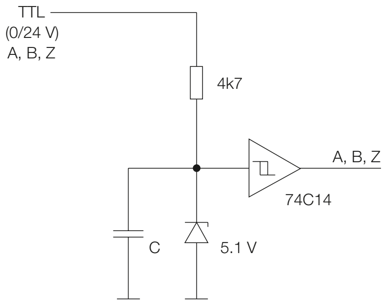


Fig. 2-25: High Threshold Logic circuit (HTL)

ℹ If the sensor is supplied with voltage that is isolated from the processing electronics, the GND for this voltage must be connected to the GND of the processing electronics.

In Figs. 2-13 and 2-14 circuit examples for the processing electronics are shown for the RS422 and HTL interface. The termination resistor Z0 for RS422 is described in the sensor user's guide. It should be used to prevent interference.

2 Interfaces (continued)

2.7.2 Relationship between maximum travel speed, resolution and edge separation

Important!

- The controller must be able to count the specified minimum chronological edge separations indicated in the tables for the sensor head (see e.g. Tab. 2-2 and Tab. 2-3) (note counting frequency of the controller!).
- The min. edge separation can even occur at a standstill due to the internal interpolation process.
- Always select the next-higher travel speed or the next-largest min. edge separation, otherwise position detection errors may be created by the controller during measured value evaluation.

Min. edge separation	V_{max} corresponding to edge separation and resolution			
	Resolution			
	1 µm	2 µm	5 µm	10 µm
0.11 µs	5 m/s	10 m/s	20 m/s	20 m/s
0.26 µs	2 m/s	4 m/s	10 m/s	20 m/s
0.42 µs	1 m/s	2 m/s	6 m/s	12 m/s
0.94 µs	0.6 m/s	1.2 m/s	3 m/s	6 m/s
1.8 µs	0.3 m/s	0.6 m/s	1.6 m/s	3.2 m/s
3.5 µs	0.15 m/s	0.3 m/s	0.79 m/s	1.5 m/s
7 µs	0.079 m/s	0.15 m/s	0.39 m/s	0.79 m/s
14 µs	0.039 m/s	0.079 m/s	0.19 m/s	0.38 m/s
21 µs	0.026 m/s	0.052 m/s	0.13 m/s	0.26 m/s

Tab. 2-2: Example of a selection table for max. travel speed, resolution and min. edge separation

The min. edge separation determines the min. count frequency which the processor must be capable of:
Minimum count frequency = 1/ minimum edge separation
Accordingly the sampling frequency must be double the value of the count frequency.
The signal frequency of the A- and B-signals is ¼ of the minimum count frequency. The relationships are shown in Tab. 2-3.

Min. edge separation [µs]	Min. counting frequency [kHz]	Min. sampling rate [kHz]	Signal frequency [kHz] Fundamental
0.11	9091	18182	2273
0.26	3846	7692	962
0.42	2381	4762	595
0.94	1064	2128	266
1.80	556	1111	139
3.50	286	571	71
7.00	143	286	36
14.00	71	143	18
21.00	48	95	12

Tab. 2-3: Example of a table for minimum edge separation

Determination of a suitable sensor for the available controller:

Example (see Tab. 2-2):

Assumptions:
- Your controller can detect a min. edge separation of 0.5 µs. If there is no sensor with this min. edge separation, select a sensor with a larger edge separation.
- The max. movement speed of the system should be 1 m/s.

Determination of a suitable sensor:
- You need a sensor with min. edge separation 0.94 µs
- To be able to travel at max. 1 m/s, select the type with a resolution of 2 µm

Determination of a suitable controller for the existing sensor

What max. counting frequency is required of the controller?
The period of the input signal is four times the edge separation.
The max. frequency of the input signal is then 1/(4 x edge separation).

Example:
For an edge separation of 0.94 µs the max. frequency of the input signal is 1/(4 × 0.94 µs) = 266 kHz.
The max. counter frequency for a 4x evaluation = 1/edge separation = 1/0.94 µs = 1.064 MHz.

The minimum count frequency which the controller must be capable of at minimum count frequency = 1/minimum edge separation is determined from the minimum edge separation.
Accordingly the sampling frequency must be double the value of the count frequency.
The signal frequency of the A- and B-signals is ¼ of the minimum count frequency. The relationships are shown in Tab. 2-2.

3 Appendix

Checklist for startup and service

- ☐ Tape attached per FMEA?
- ☐ Correct orientation of tape to sensor head?
- ☐ Optional: Cover tape applied?
- ☐ Sensor head attached per FMEA? Torque setting________
- ☐ Sensor head correctly connected (electrical)?
- ☐ Supply voltage correct?
- ☐ Output signals have correct polarity and phase?
- ☐ All connectors plugged in?
- ☐ Cable strain relief on sensor head?
- ☐ Cable routed so that interference from other cables is prevented?
- ☐ Maximum distance between sensor head and tape not exceeded over the entire range of motion?
- ☐ Lateral offset between sensor head and tape not exceeded over the entire range of motion?
- ☐ 120-Ω termination resistor between differential signals +sin/−sin and +cos/−cos connected/enabled?
- ☐ Function check with manual movement: Do all signals +sin, −sin, +cos, −cos arrive at the controller with correct amplitude and phase?
- ☐ Direction of the electrical signals correct?
- ☐ Magnitude determination $Z = \sqrt{(A^2 + B^2)}$ enabled?
- ☐ Function check: motorized movement at maximum speed?
- ☐ Is magnitude at maximum travel speed correctly determined?

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