Verification of the requirements placed on non-certified measuring instruments for safe evaluation of sine-cosine signals

ACOPOSmulti with SafeMC SinCos

1 General

The requirements listed below must be met for safety-related evaluation of a non-certified position measuring instrument on an ACOPOSmulti with SafeMC SinCos (8BVIxxxxHxSA.00x-1 inverter module). The requirements must be assessed and confirmed by the measuring instrument manufacturer.

2 Measuring instrument list

The following measuring instruments will be assessed:

Manufacturer	Measuring instrument type

Table 1: Measuring instrument list

3 Technical data

The measuring instruments must correspond to the technical data for the evaluation circuit listed in table.

Technical data encoder interfaces [1]		**Requirements met (yes/no) / Comments**
Encoder supply		Yes No
Output voltage	5 V ±5% [1]	☐ ☐
Load capability	300 mA [1]	☐ ☐
Sense lines	2, compensation of max. 2 x 0.7 V	Assessment not necessary because this refers to properties of the evaluation circuit.
Protective measures Short circuit protection	Yes	
Sine/Cosine inputs		Yes No
Signal transmission	Differential signals, symmetrical	☐ ☐
Differential voltage In motion	0.5 to 1.35 V [1]	☐ ☐
Differential voltage At a standstill	0.8 to 1.35 V [1]	☐ ☐
Differential voltage deviation per signal period	±10% [1]	☐ ☐
Common-mode voltage	Max. ±7 V	☐ ☐
Terminating resistor	120 Ω	☐ ☐
Max. input frequency	200 kHz	☐ ☐
Signal frequency (-5 dB)	<300 kHz	☐ ☐
Signal frequency (-3 dB)	DC up to 200 kHz	☐ ☐
ADC resolution	12-bit	Assessment not necessary because this refers to properties of the evaluation circuit.

1) Only shielded cables are permitted to be used.
The stranded wire for the analog interface (Sin, nSin, Cos, nCos, Ref, nRef) and the digital interface (T, nT, D, nD) must be twisted pair with a wave impedance of 120 Ω ±10%.
Additional shielding of the analog interface is recommended.

2) During the power-on procedure for the encoder supply voltage (2 seconds), the monitoring limit for the supply voltage is increased from 5.25 V to 6 V. In this phase, overvoltages up to 6 V are not detected.
A short-term overvoltage of maximum 6 V should not damage the encoder electronics in any way.
An undervoltage on the encoder supply will result in a sine or cosine signal outside the specification.

3) An actual reserve of 12 mA exists for the terminating resistor.

4) The sine-cosine output signals from the measuring equipment are checked by the evaluation circuit using pointer length monitoring.
The pointer length $z = 2 \sqrt{((Sin - nSin)^2 + (Cos - nCos)^2)}$ is monitored according to the specified limits.

5) The sine-cosine output signals from the measuring equipment are checked by the evaluation circuit using pointer length monitoring.
The pointer length $z = 2 \sqrt{((Sin - nSin)^2 + (Cos - nCos)^2)}$ is also monitored according to the specified limits from the time the evaluation circuit is switched on until a signal period has passed.

6) The sine-cosine output signals from the measuring equipment are checked by the evaluation circuit using pointer length monitoring.
The pointer length $z = 2 \sqrt{((Sin - nSin)^2 + (Cos - nCos)^2)}$ is only permitted to vary by maximum ±10% per signal period.

4 Error list for movement and position sensors

The measuring instrument must meet the requirements in table "Error list for movement and position sensors in accordance with EN 61800-5-2:2007" (Table D.16).

No.	Fault description	Fault exclusion	Description	Requirements that must be met by the measuring instrument manufacturer or machine manufacturer	Requirements met (yes/no) / Note Yes No
8	Parts become loose at a standstill: • Sensor housing comes off motor housing • Sensor shaft comes off motor shaft	FMEA and proof of fatigue strength of mechanical attachment	Output signal indicates a speed of zero. If fault exclusion is employed, the fastening mechanism for the sensor housing on the motor housing and the sensor shaft on the motor shaft generally withstands overstressing up to a factor of approximately 20x and any special maintenance information must be provided.	Always employ fault exclusion using a suitable mount. Exceptions: When used with synchronous motors that have an encoder linked to position control, it is possible to locate a possible error using the safe lag error monitoring included in the SafeMC module.	☐ ☐
9	Fastening mechanism comes loose during movement: • Sensor housing comes off motor housing • Sensor shaft comes off motor shaft	FMEA and proof of fatigue strength of mechanical attachment	Potential effect: • Static offset of sensor shaft • Dynamic slippage of sensor shaft • Output signal is incorrect / indicates a speed of zero If fault exclusion is employed, the fastening mechanism for the sensor housing on the motor housing and the sensor shaft on the motor shaft generally withstands overstressing up to a factor of approximately 20x and any special maintenance information must be provided.	Always employ fault exclusion using a suitable mount. Exceptions: When used with synchronous motors that have an encoder linked to position control, it is possible to locate a possible error using the safe lag error monitoring included in the SafeMC module.	☐ ☐
10	Measuring element comes loose[a)] (e.g. optical encoder disc)	None	Output provides incorrect position information.	An error that would lead to a position deviation larger than ±1/2 of a signal period must change the sine-cosine signal enough that pointer length monitoring detects an error. The error must be assessed by the measuring instrument manufacturer.	☐ ☐
11	No light in front of sensor diode	None	-	An error that would lead to a position deviation larger than ±1/2 of a signal period must change the sine-cosine signal enough that pointer length monitoring detects an error. The error must be assessed by the measuring instrument manufacturer.	☐ ☐
Additional requirements for rotary encoders with sin/cos output signals, analog signal generation					

Table 2: Error list for movement and position sensors using the standardized error model in accordance with EN 61800-5-2:2007 (Table D.16)

No.	Fault description	Fault exclusion	Description	Requirements that must be met by the measuring instrument manufacturer or machine manufacturer	Requirements met (yes/no) / Note Yes No
12	Static signal on inputs and outputs, individual or on multiple signals, amplitude in the voltage supply range	None	-	The output signals (sine and cosine) must be generated independently. If this requirement is met, the error is detected by pointer length monitoring on the SafeMC module with a diagnostic coverage (DC) of 99%.	☐ ☐
14	Swapping the sine and cosine output signal	Fault exclusion permitted if no electronic components are used to select an output signal from multiple sources.	-	Fault exclusion is required by the measuring instrument manufacturer.	☐ ☐
Additional requirements for encoders [b] with synthetically generated output signals					
21	Distortion of the output signals in any way	None	-	Synthetically generated output signals are not permitted to be used. Exception: Encoders with safety certification, as long as the encoder meets safety requirements when detecting errors.	☐ ☐
Additional requirements for linear encoders					
23	Mount for read head broken	FMEA and proof of fatigue strength of mechanical attachment	If fault exclusion is required, the sensor mounting usually withstands the overstressing that takes place and specific maintenance information should be specified.	Always employ fault exclusion using a suitable mount. Exceptions: When used with synchronous motors that have an encoder linked to position control, it is possible to locate a possible error using the safe lag error monitoring included in the SafeMC module.	☐ ☐
24	Static offset of measuring element [a] (e.g. optical encoder strips)	None	-	An error that would lead to a position deviation larger than ±1/2 of a signal period must change the sine-cosine signal enough that pointer length monitoring detects an error. The error must be assessed by the measuring instrument manufacturer.	☐ ☐
25	Damaged measuring element [a] (e.g. optical encoder strips)	None	Pulse shape changed. Pulses missing on incremental encoders	An error that would lead to a position deviation larger than ±1/2 of a signal period must change the sine-cosine signal enough that pointer length monitoring detects an error. The error must be assessed by the measuring instrument manufacturer.	☐ ☐
NOTE: This table was written assuming the use of optical sensors. If other sensors are used (e.g. inductive sensors), then the respective errors apply					

Table 2: Error list for movement and position sensors using the standardized error model in accordance with EN 61800-5-2:2007 (Table D.16)

a) Does not apply to resolvers
b) Also applies to linear encoders

5 EMC testing

Requirement	Requirements met (yes/no) / Note Yes No
The necessary EMC tests must conform with the higher testing levels according to IEC 61326-3-1. The measuring instrument manufacturer or machine manufacturer must provide proof that the measuring instrument conforms with the higher testing levels!	☐ ☐

Table 3: EMC testing

6 Safety integrity

In order to asses safety integrity, the measuring instrument manufacturer must provide the following characteristics. These values can then be used to calculate the PFH for the encoder via diagnostics and encoder evaluation and therefore assess the safety integrity of the entire system.

Value	Unit	Shortcut	Description
MTTF	[h]	Mean time to failure	The MTTF can be directly used to asses safety concepts in accordance with EN ISO 13849. The MTTF (mean time to failure) can be performed for components by analyzing field data or by predictive analysis. At a constant failure rate, the average of the failure-free operating time MTTF = 1/λ , whereby λ is the failure rate of the instrument. (statistically, the assumption can be made that 63.2% of affected components will experience failure after the MTTF has expired.)
MTBF	[h]	Mean time between failure	The MTBF is the operating time between two successive failures of a measuring instrument that is in use.
λ λ_D λ_S	[10^{-9} 1/h],[FIT]	Failure rate (failures over time) Dangerous failure rate Safe failure rate	To asses the safe failure rate according to DIN EN 61508, the FIT value (reciprocal of the MTTF value) must be used as failure rate. If no detailed breakdown of failure rates ($\lambda_F = \lambda_{F1} + \lambda_{F2} + \ldots + \lambda_{Fn}$) is specified for the measuring instrument used, the default rate is equally distributed among the faults accounted for in table D.16 of the error model to DIN EN 61800-5-2. If no detailed breakdown of failure rates ($\lambda_F = \lambda_S + \lambda_D$) is specified for the measuring instrument being used, then 50% of the failures will be assumed dangerous in accordance with EN ISO 13849.

Table 4: Characteristics required for non-certified SinCos measuring instruments

Manufacturer	Measuring instrument type	Safety integrity

Table 5: Safety integrity: Measuring instruments

7 Confirming correctness of the specified information

I hereby confirm the correctness of the information specified by the manufacturer.

Manufacturer	
Name	
Address	

Signature	
Location, Date	
Name, Title	
Signature