SIN-COS interface and temperature sensor

Summary

The SIN-COS electrical interface option is based on linear Hall sensors that are providing sine and cosine signals. This type of interface is to be used for commutation as well as for position or speed control applications.

The dimensions and connection type are same as the 22xx BX4 drive with the analog or digital interface. Therefore for the application where the compact design with minimum wiring effort are required, this type of interface is ideally suited.

The interface option can be combined with the 3rd generation of motion controllers MC3. Even designing own application specific control system based on an analog-to-digital conversion becomes easy due to the superior signal quality.

The SIN-COS Hall sensor based interface described in this application note is the single-ended, with typically peak-to-peak 2.5V and provides 2 periods per one mechanical motor revolution of the drive. The detailed electrical characteristics are described in the table 2 and 3. Here it is important to note that, this SIN-COS Hall sensor based interface is different from the standard industry based differential 1Vpp sine-cosine interface.

In addition to SIN-COS interface, the drive also has an integrated temperature sensor output to get thermal status of the drive. Further details are given below in the section – temperature sensor.

Applies To

BX4 Motor-type	Option-No SIN-COS	Compatible controllers
2232…BX4	5327	MC3001
2250…BX4		MC5004
		MC5005
		MC5010

Table 1 Motors that are equipped with SIN-COS interface and temperature sensor

Description

General Information

The FAULHABER 22 BX4 brushless-motor with SIN-COS interface uses the magnetic field of the rotor magnet for sensing purpose and therefore has a very compact design.
For the 2 pole-pair BX4 motor, two sine and cosine periods per one complete mechanical rotation are available. The 90° phase shift between sine and cosine allows determination of the actual angle.

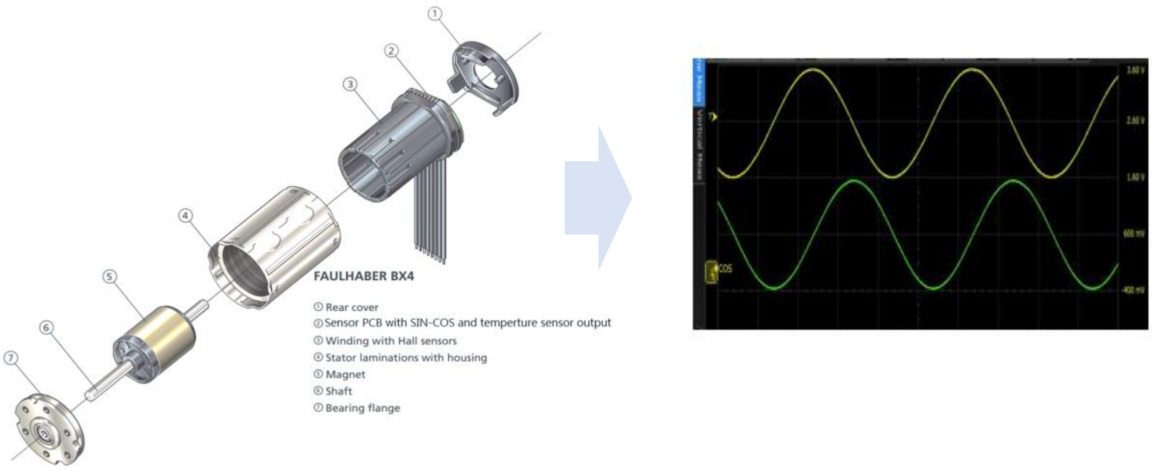


Figure 1 : Principle of sine-cosine signals for BX4 motors

Electrical characteristics of the Hall sensors

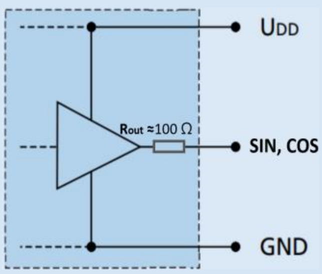
BLDC motor family	BX4-Motors
Motor types	2232…BX4, 2250…BX4
Sensor supply voltage U_{DD} (min. / typ. / max.) V	(4.5 / 5 / 5.5)
Total current consumption I_{DD} (min./ typ. / max.) mA	(- / 15 oder 21 / 27)
Output stage type	Push-Pull
Max. output current capacity/channel mA	

Table 2 Electrical characteristics of Hall-sensors used for SIN-COS interface

Specification - sine and cosine signals

The electrical signal characteristics are specified in the table 2:

	minimum	nominal	maximum
Phase-to-Phase offset	82°e	90°e	98°e
Offset voltage U_{offset}	2.20V	2.5 V	2.8 V
Peak-to-peak voltage U_{ss}	1.7V	-	3.5 V
Maximum voltage U_{max}	3.0V	-	4.2 V
Amplitude Deviation $U_{max\text{-}diff}$[1]	0V		0.09 V
Position error[2]	-	1°m	-
Repeatability[3]	-	0.2°m	-

Table 3 Output signal specification range for the measuring parameters

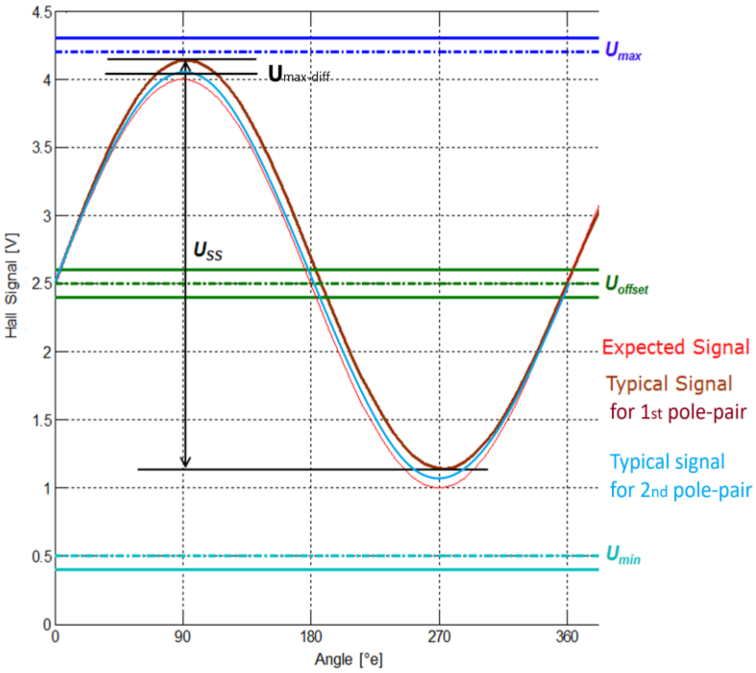


Figure 2 Definitions of analog sine/cosine signal parameters

[1] Amplitude deviation describes the different maximum signal levels in different magnetic pole-pairs of brushless motors having 2+ pole-pairs.

[2] For the definition of the Position error, please refer Appnote - 147

[3] For the repeatability of the Position error, please refer Appnote - 147

Commutation sequence and phase alignment

The commutation sequence for the FAULHABER BLDC motors is as in the table 4 below:

Direction	Commutation sequence
Clockwise (CW)	Phase A - Phase C – Phase B
Counter-clockwise (CCW)	Phase A- Phase B – Phase C

Table 4 FAULHABER BLDC motor the commutation sequence

For the measurement calculations, the signal offset of 2.5V subtracted so that the angle at the zero crossing of the signals can be considered. Figure 3 and 4 shows the alignment of the phase voltage V_{AB} with respect to the COS signal of the drive. For the clockwise (counter-clock wise) operation of the 2250BX4 drive, the zero crossing of sensor V_{AB} is shifted typically +15°m (-15°m) from the zero-crossing of the COS signal.
For the 2232 BX4 drive, this angle is +10°m (-10°m).

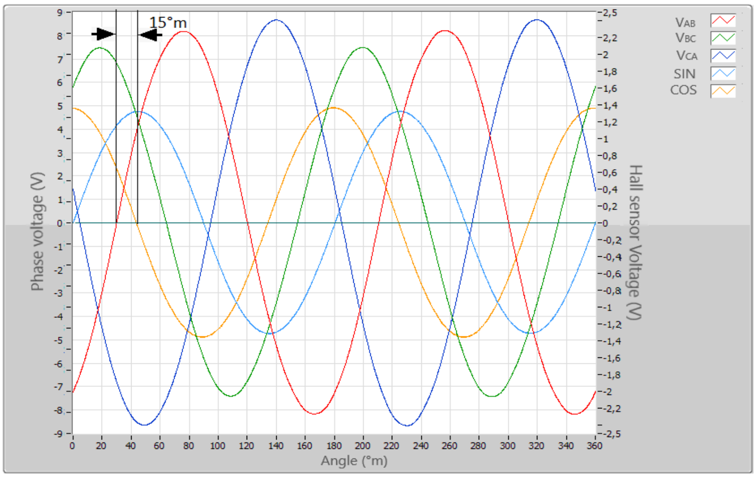


Figure 3 Signal profile of 2250 BX4 drive with the clockwise operation

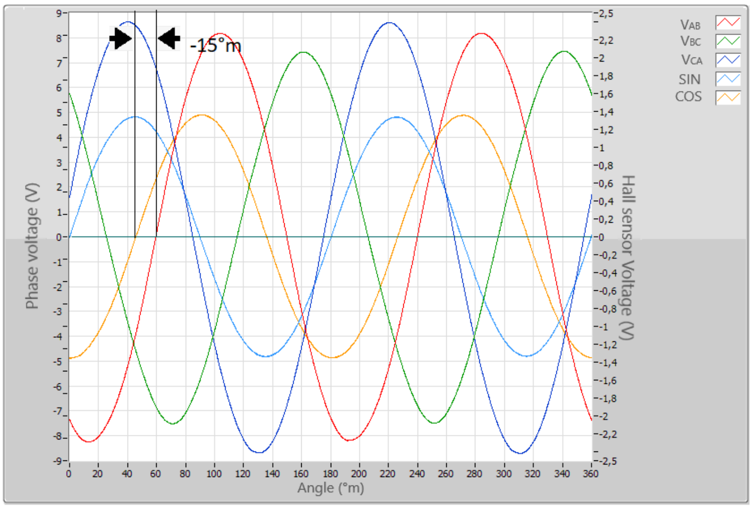


Figure 4 Signal profile of 2250 BX4 drive with the counter-clockwise operation

Calculation of rotor angle and speed

To determine the electrical angle of the system, the sine (α) and cosine (β) output signals are fed into an arctan calculation, with the sine signal being alpha and the cosine signal being beta. For speed calculation a further deviation is required. Please consider that due to 2-pole pairs, there are 2 signal periods per motor revolution.

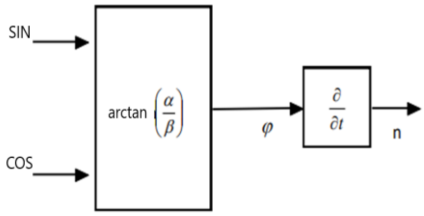


Figure 5 Block diagram for position and speed calculation

Temperature sensor

Temperature monitoring is one of the most effective ways to protect a motor from overheating.
FAULHABER motors with a SIN-COS interface provide an integrated temperature sensor placed next to the motor winding with the motor winding being the hot-spot of the system.
Here a surface mounted Negative Temperature Coefficient (NTC) sensor is used.
The NTC sensor is a type of resistor that decreases the resistance as the temperature increases.

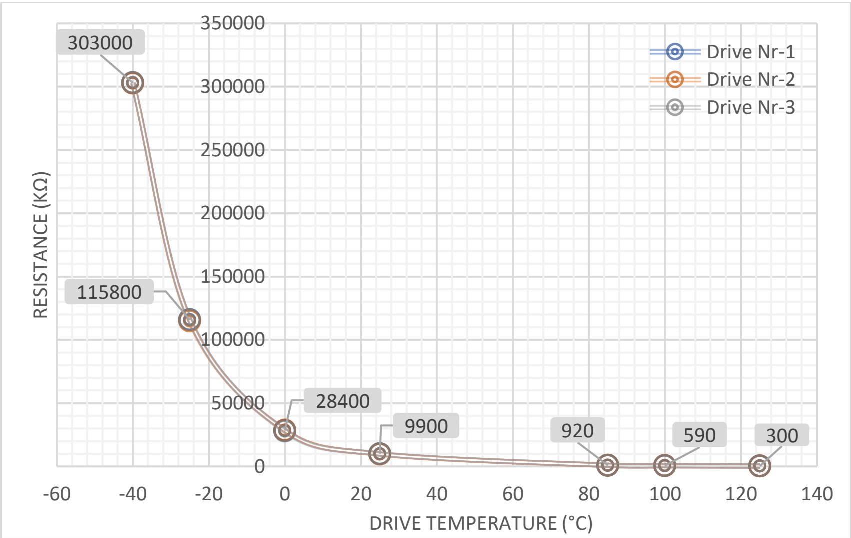


Figure 6 Graphical characteristic of NTC resistance over internal motor temperature

The relationship between NTC-resistance and temperature is a non-linear function. The figure-3 shows the examples of three drives with their NTC-characteristics measured.
Mathematical representation of the relation between NTC-resistance and temperature is as follows:

$$T(R) = \frac{T1}{1 - \frac{T1}{B} . \ln \frac{R1}{R2}}$$

Where:
T(R) is the temperature to be calculated in Kelvin
T1 is the first temperature point in Kelvin (at room temperature 25°C, it is = 298.15K)
R1 is the resistance at T1 temperature in Ohms (at room temperature 25°C, it is = 10kΩ with tolerance ±3%)
R2 is the resistance at T(R) temperature in Ohms
B is the constant that depends up on type of ceramic material. Its value for temperature range (-40 to 125°C) is 4110 with tolerance ±3%.

Connection diagram with Motion controller

The SIN-COS interface including the NTC-sensor output can be connected directly to the FAULHABER motion controller - generation MC3 with the use of 5-pin connector M2.

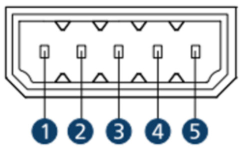
	Pin Number	Designation	Description
	1	U_{DD}	Power supply for sensors
	2	GND	Ground connection
	3	COS	Cosine output signal
	4	SIN	Sine output signal
	5	NTC	Temperature sensor output signal

Table 5 Pin-assignment of sensor connection M2 of FAULHABER-MC3

For configuration of the sin/cos sensor interface use Motion Manager's motor wizard "select motor" and select the sensor system "analog hall sensors" with 2 channels (sin/cos) as in figure below:

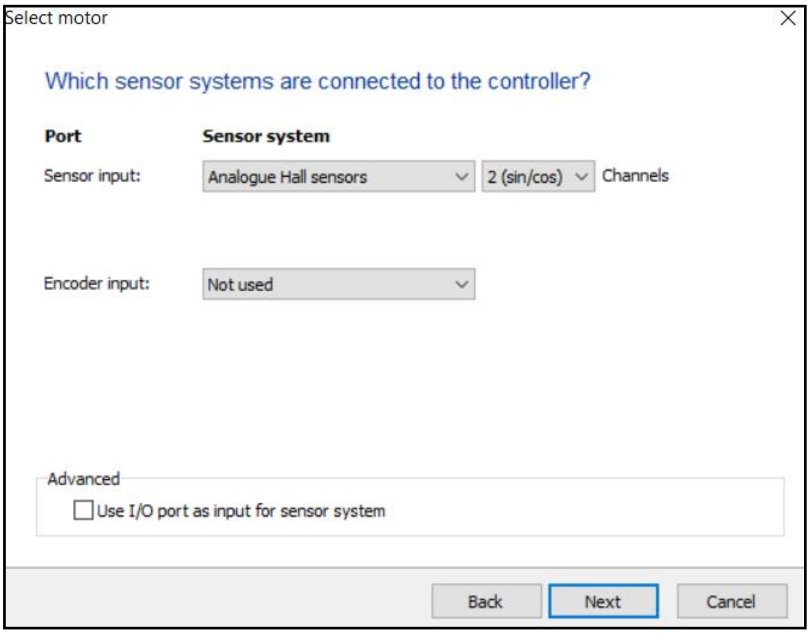


Figure 7 Configuration – motor with sin-cos interface with MC3

The 2250 BX4 drive require the offset-angle correction typically 5°m (1821 x 0.00549°el=10°el) and can be programmed within the object browser as below in figure 8.
The 2232 BX4 drive does not require any offset angle correction programming.

Objekt	Index	Subindex	Parameter	Aktueller Wert	Neuer Wert	Einheit
Motor and application data for motor control	2329	08	Phase angle offset	1821		x0.00549 °(elec.)

Figure 8 Offset angle programming for 2250 BX4 drive

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