Digital Hall Sensors

Introduction

Hall based sensors are a widely used sensor system that provides the rotor position feedback to the motor controller. All FAULHABER BLDC motors have integrated digital hall sensors as the standard version. Digital hall sensors are used for the trapezoidal commutation for the speed control applications. The digital hall sensors are in general very economical, compact and ease to use with speed controllers.

Related products

2-Pole Motors	4-Pole BX4 Motors	4-Pole BP4 Motors	4-Pole Flat Motors	7-Pole Flat Motors
0620…B	2232…BX4 (S)	2264…BP4	1509…B	2214…BXT
0824…B	2250…BX4 (S)	3274…BP4	1515…B	3216…BXT
1028…B	3242…BX4		2610…B	4221…BXT
1218…B	3268…BX4		2622…B	
1226…B				
1628…B				
1645…B				
1660…B				
2036…B				
2057…B(HS)				
2444…B				
3056…B				
3564…B				
4490…B(S)				

Table 1 Motors that can be equipped with digital hall sensors

Speed Controller	Motion Controller V3.0
SC 1801	MC3001
SC 2402	MC3602 / MC3606
SC 2804	MC3603
SC 5004	MC 5004
SC 5008	MC 5005
	MC 5010

Table 2 FAULHABER Motion Controllers and Speed Controllers supporting digital hall-sensors

Glossary

There are a few special terms in this product application note:

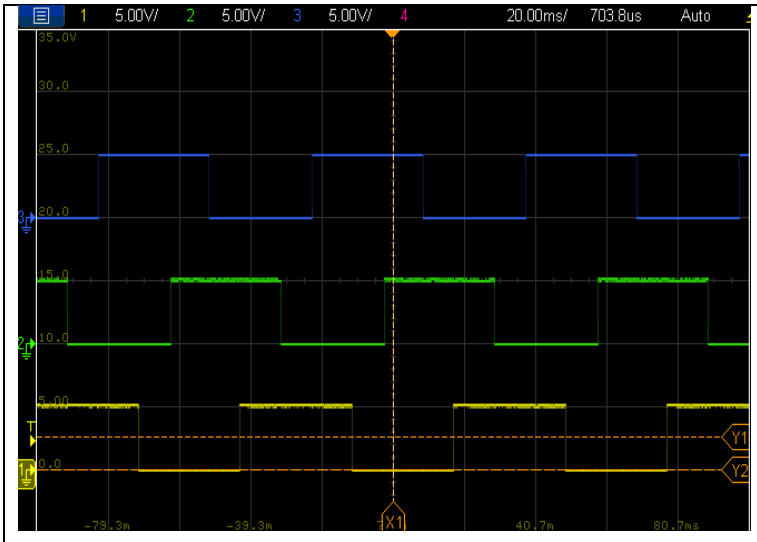
120°e	The °e denotes an electrical angle of a motor. Here we are mostly discussing the electrical view of a motor – so the angle within on electrical period of the hall-sensors or the voltages. In motors having more than one pole pair, there is a multiple of electrical periods per mechanical turn.
Speed Controller	The FAULHABER controllers used for pure speed control of a motor
Motion Controller	The FAULHABER controllers used for the servo-drive applications
B	FAULHABER BLDC B motors family
BX4	FAULHABER BX4 motors family
BP4	FALUHABER BP4 motors family
BXT	FAULHABER flat BLDC motors family

Description

General Information

For a standard 3 phase BLDC motors, the sensors generate three square wave signals ($Hall_A$, $Hall_B$, $Hall_C$) with a duty cycle of 180° each shifted with 120°. These results in a switching pattern of three digital signals which generate a unique sequence code for every 60°. In other words, the three sensor signals can give a rotor position with a resolution of 60° electrical. For the multi-pole motors, the electrical revolutions per one mechanical revolution are multiple of pole pairs.

The purpose of trapezoidal-commutation is to energize the stator phase windings in a certain sequence. The torque production is caused by the attraction and repulsion between stator field and permanent magnets of the rotor.



The sensors are positioned with 120 °e angle. This allows for simple trapezoidal-commutation. The motor-speed can be calculated too.

Digital hall-sensors are mainly used for simple speed control or in combination with an additional incremental encoder.

Yellow: $Hall_A$

Green: $Hall_B$

Blue: $Hall_C$

Clockwise operation

Figure 1 Digital hall sensors

Electrical characteristics of the hall sensors of FAULHABER BLDC motors

BLDC motor family	B motors			
BLDC motor types	0620…B 1218…B 1226…B *)	2057…B(A)	1628…B 2036…B, 2444…B 3056…B, 3564…B 4490B(S)	0824…B 1028…B 1645…BHS 1660 BHS(T)
Supply voltage range [V] min. / typ. / max.	2.5 / - / 5.5	3.5 / - / 24	4.5 / - / 24	4.5 / 5 / 5.5
Current consumption [mA] min. / typ. / max.	- / 7 / 10	- / 9 / 15	- / 24 / 35	- / 16 / 23
Max. output current per channel [mA]	-5 / 20	40 (sink)	20 (sink)	4
Output stage type	Push-pull	Open-drain	Open-collector	Push-pull
Typical external pull up resistor [kΩ], when using a 5V supply	Not required	1 ... 5		not required
Reverse polarity protection		-	☑	-
Number of pole-pairs	1			

Table 3 Electrical characteristics of digital hall sensors in FAULHABER 1 pole-pair BLDC motors

*) for special executions please contact FAULHABER support team

BLDC motor family	BX4 motors with IE3 encoder and digital hall	BX4 motors with digital hall, only	BP4 motors	Flat motors	
BLDC motor types	2232…BX4 (S) 2250…BX4 (S) 3242…BX4 3268…BX4	2232…BX4 (S) 2250…BX4 (S) 3242…BX4 3268…BX4	2264…BP4 3274…BP4	1509…B 1515…B 2610…B 2622…B	2214…BXTR(H) 3216…BXTR(H) 4221…BXTR(H)
Supply voltage range [V] min. / typ. / max.	4.5 / 5 / 5.5	2.2 / - / 18	2.7 / - / 24	2.2 / - / 20	2.7 / - / 24
Current consumption [mA] min. / typ. / max.	- / 16 / 23	4.5 / 9 / 15	4.5 / 9 / 14	- / 6 / 12	4.5 / 9 / 14
Max. output current per channel [mA]	4	40 (sink)	40 (sink)	25 (sink)	40 (sink)
Output stage type	Push-pull	Open-drain			
Typical external pull up resistor [kΩ], when using a 5V supply	not required	1 ... 5			
Reverse polarity protection	-	-	☑	-	☑
Number of pole-pairs	2		2	2	7

Table 4 Electrical characteristics of digital hall-sensors in FAULHABER 2 and 7 pole-pair BLDC motors

Pull-up resistor

When the digital hall sensors are using an open drain or open collector output stage, pull up resistors are required. The pull-up resistors (R_{PU}) are simple fixed-value resistors connected between the output terminal and supply voltage terminal of the hall sensor.

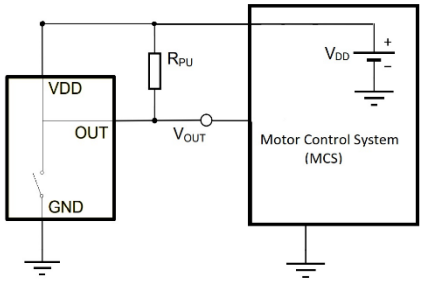


Figure 2 Digital hall sensor with pull-up resistor interfaced to controller

A rule of thumb is to use a resistor that is at least 10 times smaller than the value of the input pin impedance of the motor controller. In bipolar logic families which operate at 5 V, the typical pull-up resistor value is 1 kΩ to 5 kΩ. The FAULHABER speed controllers using typically 2 kΩ as the integrated pull-up resistors, therefore drawing typically 2.5mA through the sensor output pin.

Specification of digital hall signals

The general electrical signals of digital hall-sensors are specified as below:

	minimum	nominal	maximum
Phase-to-Phase offset (°e)	**112**	**120**	**128**
Duty cycle (%)	**45**	**50**	**55**
Step angle S (°m) - **B motor family**	**50**	**60**	**70**
Step angle S (°m) - **BX4, BP4 motor family**	**20**	**30**	**40**
Step angle S (°m) - **BXT motor family**	**5.6**	**8.6**	**11.6**

Table 5 Signal specification of digital hall sensors in FAULHABER motors

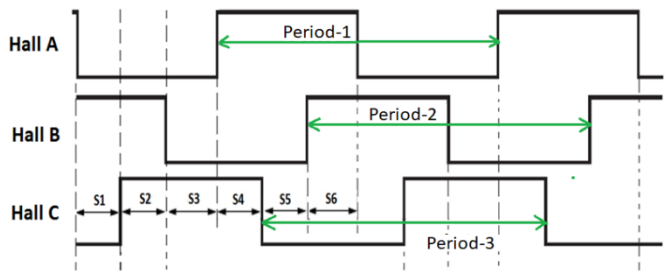


Figure 3 Example of digital Hall signal

Trapezoidal commutation of BLDC motors with FAULHABER controllers

The following Table-6 gives the details of the motor phases switching sequence for a given hall signal pattern to rotate in clockwise and in counterclockwise direction. The switching states „1" and „0" represent the high and low logic level of the digital hall sensors respectively.

Depending upon the hall states (Hall A, Hall B, Hall C), the voltage across the motor phases changes accordingly. For instance, in the Hall state 1-0-1 in clockwise direction, the path of the current begins at the positive pin of the voltage source, flows through the phase A and B of motor windings, finally to the ground pin. At that instance, the motor phase C is remains open (marked with '-' sign in Table-6).

Hallsignals			Motor Phases			Commutation States	
Hall A	*Hall B*	*Hall C*	*MotA*	*MotB*	*MotC*		
Clockwise Direction (CW)							
0	0	1	-	GND	Umot	6	Step Sequence Reverse
0	1	1	GND	-	Umot	5	
0	1	0	GND	Umot	-	4	
1	1	0	-	Umot	GND	3	
1	0	0	Umot	-	GND	2	
1	0	1	Umot	GND	-	1	
Counterclockwise Direction (CCW)							
0	1	0	Umot	GND		1	Step Sequence Forward
0	1	1	Umot		GND	2	
0	0	1	-	Umot	GND	3	
1	0	1	GND	Umot		4	
1	0	0	GND		Umot	5	
1	1	0	-	GND	Umot	6	

Table 6 Trapezoidal commutation excitation sequence with digital hall sensors

Figure 4, shows the signal characteristics of a BLDC motor over one electrical revolution. The hall signals (A, B,C) along with the phase voltages (A,B,C) reflect the clockwise sequence mentioned in the table-6. The motor winding's back-EMF (A-B, B-C, C-A) is added here to show that they are phase shifted by 60°e compared to the corresponding hall signals. This relationship and the excitation sequence are applicable to all the FAULHABER motor families with a digital hall sensor interface.

For multi-pole BLDC motors families, the electrical resolution per one mechanical revolution is as multiple of pole pairs. For instance, a BXT motor with 7 pole-pairs requires 7 electrical revolutions in one mechanical revolution.

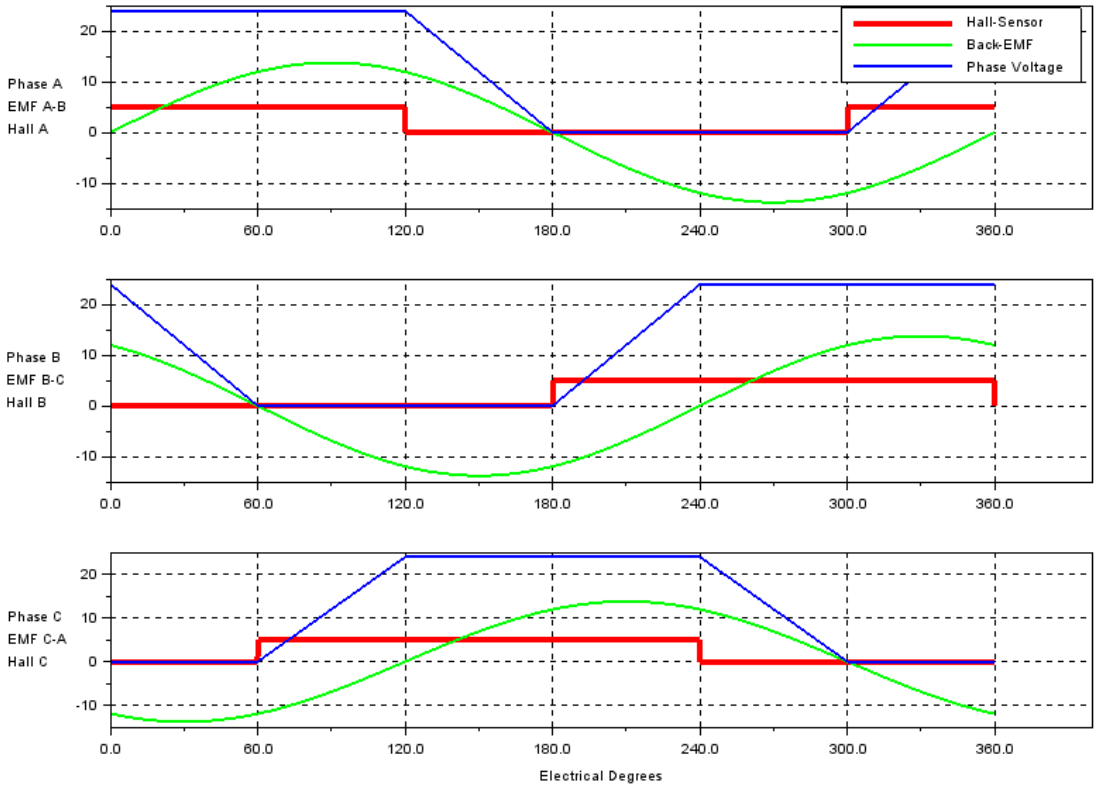


Figure 4 Phase voltage, Back-EMF and Hall sensor signals for one electrical revolution (cw)

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