

Support of Third Party BLDC motors

Summary

Overview of supported / required characteristics of third party BLDC motors.

Step by step instruction of setting up:

- a **third party** BLDC motor with **digital hall** sensors (+ incremental encoder)
- to operate with a MC3 Motion Controller
- using Motion Manager 6.3

Applies To

Faulhaber Motion Controller MC5004, MC5005 and MC5010



Description: Specification of third party BLDC motor / controller combination

Supply voltage	up to 50	V
Electrical time constant L / R	up to 2.5	ms
# of pole pairs	up to 12 (= 24 poles)	
Torque constant	up to 200	mNm / A
Commutation sources	 Digital hall sensors (+ incremental encoder): Block commutation or Sinusoidal commutation in combination with incremental encoder, only 	
Actual Sources of Velocity and Position	 Digital hall sensors (not as positon source) Incremental encoder (recommended as postion and velocity source) for absolute encoder, see also AppNote 158 	
Total inertia J _{Motor} + J _{Load} (J _{Load} reduced to motor-side)	 up to approx. 4000 = 0.0004 with kJ = ((J_{Motor} + J_{Load}) / J_{Motor}) ideally <= 4 	gcm² kgm²
Hall sensor phasing	120	o
Alignment of hall sensors with EMF	 Supported: Hall sensors / EMF shifted by 60° (default) Hall sensors / EMF shifted by 240° (inverted) Other alignments in combination with sinusoidal commutation, only. (Adjusment of phase anlge offstet parameter required, which is not explained here) 	
Commutation Sequence	 Supported sequences for clockwise rotation: C-B-A (default) A-B-C 	
Lead labels	• usually: A = U = 1 B = V = 2 C = W = 3	



Step by Step instruction

1. Carefully compare the motor datasheet with the specification on page 2 and the following tables and diagrams to identify if your third party motor is supported and which use case applies. Contact your motor supplier if the datasheet does not provide any comparable information.

Excitation sequences and hall sensor output tables of major use cases for clockwise (cw) rotation:

Alignment of hall sensors with EMF - shifted by +60° Phases Sensors **Electrical Degrees** Α В С А В С 0 - 60° 1 0 0 High Low х 60 - 120° 1 0 1 High Low х 120 - 180° 0 1 Low 0 х High 180 - 240° 1 1 High 0 Low Х 240 - 300° 1 0 0 Low High Х

300 - 360° 1 1 0 High х Low

Hall sensor outputs and excitation sequence

(1) Default settings for FAULHABER motors Commutation Sequence: C-B-A







(2) Commutation Sequence A-B-C

Alignment of hall sensors with EMF - shifted by -60°

		Sensors	\$		Phases	
Electrical Degrees	А	В	С	А	В	С
0 - 60°	1	0	1	High	Low	Х
60 - 120°	1	0	0	High	Х	Low
120 - 180°	1	1	0	Х	High	Low
180 - 240°	0	1	0	Low	High	Х
240 - 300°	0	1	1	Low	Х	High
300 - 360°	0	0	1	Х	Low	High

Hall sensor outputs and excitation sequence



Phase-Voltages, Back-EMF and Hall-Sensor-Signals

Position Position Position P	1/min	
> Analogue I/Os]	
Communication Value: 0x01 Bit Function 0 Commutation sequence ABC 1 Reserved 2 Reserved 3 Reserved 4 Reserved 5 Reserved 6 Reserved 7 Hall signals inverted) Help	

Motion Manager Settings



(3) Commutation Sequence C-B-A

Alignment of hall sensors with EMF - shifted by +240° (= inverted to use case 1)

		Sensors	5		Phases	
Electrical Degrees	А	В	С	А	В	С
0 - 60°	0	1	1	High	X	Low
60 - 120°	0	1	0	High	Low	Х
120 - 180°	1	1	0	Х	Low	High
180 - 240°	1	0	0	Low	х	High
240 - 300°	1	0	1	Low	High	х
300 - 360°	0	0	1	х	High	Low

Hall sensor outputs and excitation sequence



Phase-Voltages, Back-EMF and Hall-Sensor-Signals

Operating modes General	 Signal management - Encode 	r - Advanceo	ł	
Velocity	Hall configuration (0x2318)			
Voltage Mode	Hall sensor type:	0x00 🥖		
Device control	Enable adaptation:	0		
Signal management	Adaptation threshold speed:	1000	1/min	
▲ Encoder	Digital hall settings of Non-Faulhaber motors:	0x80 🥖		
Digital I/Os				
 Communication 	Value: 0x80	6		
	Bit Function			
	0 Commutation sequence ABC			
	1 Reserved			
	3 Reserved			
	4 Reserved		Help	
	6 Reserved			
	7 📝 Hall signals inverted			



2. Connect the motor phases and sensor wires.

Faulhaber Controllers use the labels A, B and C. Usually this can be directly transferred to:

		Phases		ŀ	all Sensor	S
Controller	Mot-A	Mot-B	Mot-C	Sens-A	Sens-B	Sens-C
Motor	Phase_U	Phase_V	Phase_W	Hall_U	Hall_V	Hall_W
or						
Motor	Phase_1	Phase_2	Phase_3	Hall_1	Hall_2	Hall_3

- Some motors offer positive and negative digital hall sensor signals. Connect the positive ones to the controller, the negative ones are not used.
- It is likely that the motor will have an additional incremental encoder. Connect it to the Encoder input M3, making sure that Channel_A and Channel_B are not mixed up. (Using an encoder index or a line driver is optional.)

Naming of the controller connectors (MC5005 + MC5010)



3. **Connect** the **power supply** to the controller (Up and Umot)

and establish communication



4. Create a **new motor** using the motor select wizard of Motion Manager 6.3

🚋 FAULHABER Motion Manac File Edit Terminal Comma	Select Motor			X
	Which mo	otor is connected to the cont	troller?	
=	Motor type:	Brushless DC Motor	i 3 Motor connections	
်င္ပွဲ Initial Startup	Series:	3564K 🔹		
👃 🕹 Establish connecti	Types:	012B 🔻		
Select motor				
Configure controller		Create a new motor		
Operate motor		<u>View motor data</u>		
Configuration				
Drive functions				
Control parameters				
Object Browser				
🗙 Tools				
Motion Cockpit				
😹 Graphical analysis				
I Controller tuning			Back Next	Cancel
Status display	[
Macros				

When creating the motor make sure that especially the red marked parameters are correctly entered.

Type: Brushless DC Motor	•			
Motor diameter:		mm		
Motor length:		mm		
Shaft type (optional):	•			
Nominal voltage:		V		
Type of commutation + version:	•			
Special number (optional):				



Designation	Unit	Value	
Terminal resistance (R)	Ohm		
Friction torque, static (Co)	mNm		
Friction torque, dynamic (Cv)	mNm/rpm		
Torque constant (kM)	mNm/A		
Terminal inductance (L)	μH		
Rotor inertia (J)	gcm ²		
Thermal resistance (Rth1)	K/W		
Thermal resistance (Rth2)	K/W		
Thermal time constant (Tw1)	S		
Thermal time constant (Tw2)	S		
Number of pole pairs	-		
Rated current (thermal limit) (IN)	Α		

If the values for friction and thermal parameters are not available, choose the values of a similar Faulhaber motor instead (of course the thermal motor model will not be precise in this case). Then click save.

5. **Choose** the newly created **motor** by clicking next.

6. **Configure the sensors**, following the "select motor wizard"

Choose Digital Hall sensors as Sensor input. If present enter an Incremental Encoder as encoder input, as well as the number of Pulses/Rev. (The value entered here will be internally multiplied by 4 to reflect the 4-edge evaluation of the control-ler).

ect Motor		X
Which encod	er systems are connecte	d to the controller?
Port	Encoder system	
Sensor input:	Digital Hall sensors	
Encoder input:	Incremental encoder	▼ 256 ▼ Pulses/Rev.
	Without index pulse	•
Advanced		
Use I/O po	t as input for encoder system	
		Back Next Cancel



7. **Choose block commutation** by assigning digital hall sensors for commutation. If present select an incremental encoder as source for velocity and position.

Even if **sinusoidal commutation** shall be used in the application it is highly recommended to first select block commutation. Then follow the steps 8..11 for configuration and verification, and only afterwards come back to the "motor selection wizard" and choose sinusoidal commutation by assigning "digital hall sensors + incremental encoder" to the commutation angle. (Otherwise verification of the correct settings gets difficult).

all sensors tation type: Block commutation ental encoder tation train encoder tation train t
tation type: Block commutation Intal encoder
ntal encoder
ental encoder 🔹

8. **Transfer** the **configuration** to the controller and save it.

Select Motor			X
Confirm and tran	sfer configuration		
General			
Type:	Brushless DC Motor		
Motor:	3564K 012B		
🛕 The motor can b	e damaged if configured ir	ncorrectly!	
Assignment of encoder	systems		
Commutation:	Digital Hall sensors		
Velocity calculation:	Incremental encoder		
Position calculation:	Incremental encoder		
🛎 Transfer confi	guration		
Which configuration sto	eps are executed?		
		Back Finished Canc	cel

If the configuration cannot be transferred, contact your FAULHABER sales partner and provide the data which was entered during motor creation, so FAULHABER can check for compatibility with the controller.



9. **Recall the use case** which was identified in step 1 on by examining the tables and diagrams.

If use case 2 (commutation sequence A-B-C) or 3 (inverted hall signals) applies to the motor the hall configuration 2318.04 has to be modified accordingly.

Go to Configuration / Drive functions / Signal management / Encoder / Advanced:

brive functions			
Operating modes General Operating modes General Operation Velocity Outrent Outage Mode Device control Signal management General Advanced Digital //Os Analogue //Os Ocommunication	 Signal management - Encoder - Advanced 		
	Hall configuration (0x2318)	0.00	
	Hall sensor type: Enable adaptation:	0	
	Adaptation threshold speed:	1000 1/min	
	Digital hall settings of Non-Faulhaber motors:	0x01 🖉	
	Italian Audi	X	
	Bit Function		
	0 ✓ Commutation sequence ABC 1 Reserved 2 Reserved 3 Reserved 4 Reserved 5 Reserved 6 Reserved	Нер	
	7 Hall signals inverted	Cancel	

Configuration of use case 2:

Configuration of use case 3:

brive functions			
Operating modes General Operating modes General Operation Velocity Current Voltage Mode Device control Signal management General A Encoder	 Signal management - Encoder - Advanced 		
	Hall configuration (0x2318)		
	Hall sensor type:	0x00 🥖	
	Enable adaptation:	0	
	Adaptation threshold speed:	1000 1/mir	
	Digital hall settings of Non-Faulhaber motors:	0x80 🖉	
Digital I/OS Organization Communication	Value: 0x80 Bit Function 0 Commutation sequence ABC 1 Reserved 2 Reserved 3 Reserved 4 Reserved 5 Reserved 6 Reserved 7 V Hall signals inverted	Bit Help	

If use case 1 applies the value of object 2318.04 must be 0x00.



10. Testing the configuration - in voltage mode, via graphical analysis

	FAULHABER Motion Manac File Edit Terminal Comman Com	Motion Cockpit ↓ × ◇ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ <th <="" th="" th<=""></th>	
	😪 Initial Startup	Drive is switched off Switch on	
	↓ Establish connecti	Setpoint 1: 100 🔻 🔿 Go!	
		Settoint 2: 0 The Col	
Configure controller			
	Operate motor	Act. value: 0	
	Seconfiguration		
	Drive functions	Unit: 10 mV	
	Control parameters		
	Object Browser	Send setpoints alternately	
	🔀 Tools	😵 Run once	
	Motion Cockpit	Run repeatedly	
🧟 Graphical analysis			
	Controller tuning	Waiting tim 2 🔻 s	
	Status display		
	Macros		

- Open the Motion Cockpit
- Choose the voltage mode and switch the power stage on.
- Command a voltage of 1 V by tipping 100 into the "Setpoint 1" field.
- Then push the Motion Cockpit button "Go!"



 Open the Graphical Analysis and add the sources "Velocity actual value", "Motor output voltage BL block", "Current actual value" and "Actual commutation segment" (via Edit settings).



A correctly configured motor will:

- run clockwise (when looking onto the shaft)
- show a positive Velocity actual value as displayed in the above graph \checkmark

For block commutation only:

- show the typical current waveform with commutation "arcs"
- show no current spikes, expect for spikes towards zero at the point of commutaion. \checkmark

Recorder view of a reasonable Torque actual value + Commutation segments:





11. Troubleshooting

- The Velocity actual value is negative, when commanding a positive voltage
 - if an incremental encoder is used, swap the encoder channels A and B
 - if only digital hall sensors are used, it is likely that the hall sensor configuration is incorrect, see step 9, page 10.
- The motor is not running at all or not running smoothly
 - Check if the number of pole pairs (object 0x2329.07) was entered correctly (see object browser, or select motor → edit motor data)
 - Check if the correct hall sensor configuration was chosen (object 2318.04), see step 9, page 10.
 - Check the wiring, see step 2, page 6

For block commutation, only:

• The recorded graph of the torque actual value does not show the typical commutation waveform (see page 12)

Example of an incorrect current waveform:



- Check if the correct hall sensor configuration was chosen (object 2318.04), see step 9, page 10.
- Check the wiring, see step 2, page 6



- The recorded graph of the torque actual value shows spikes which are not related to the point of commutation (= when a commutation segment changes)
 - Check if the correct hall sensor configuration was chosen (object 2318.04), see step 9, page 10.
 - Check the wiring, see step 2, page 6

12. Further Steps for starting up the system

Proceed with the controller configuration wizard.

There the parameters of the feedback control system will be set according to the inertia of the system. In order to identify the inertia, the complete system including the load must be available.

Be aware that the automatic system identification was designed for slotless motors; it might not work with some slotted motors.



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