



## Application Note #5489

### Setting up a brushless motor with Galil's built in 500W servo drive

A 3-phase brushless motor requires the amplifier to provide electronic commutation. Commutation of a brushless motor means that the amplifier needs to decide which phase of the motor to energize and at what point in the magnetic cycle to energize it. Standard Galil 500W amplifiers require hall sensors to determine the point to change which phases are energized. For applications that require brushless motors to be commutated with Galil amplifiers without hall sensors please contact Galil.

Hall sensors are good for determining changes in phase however interpretation of hall sensor feedback varies between motor manufactures. For example, if hall sensor A and B are activated which phases of the motor need to be energized? The answer to this depends on how the motor was manufactured. In order for the amplifier to properly commutate the motor the user needs to wire the hall sensors and motor power leads appropriately. Galil recommends two possible methods for determining the proper wiring.

#### Method #1 – QH Command

1. Wire the 3 motor phase wires and 3 hall sensors randomly. Do not connect the motor to the load yet. A free spinning motor is recommended for testing.
2. Set the PID's to zero. (KPX=0;KDX=0;KIX=0)
3. Put the amplifier in brushed mode (BRX=1)
4. Issue a small offset with the OF command (ex OFX=1). This will cause the motor to lock into a phase at a hall transition. You should be able to feel this with your hand on the motor shaft. (ensure that controller is in SH state)
5. Now check the hall state with the QH command. If using GalilTools, it can be helpful to display \_QH in the watch window. (Note: DMC-21x3 does not have QH in the watch window)
6. Now lightly wiggle the motor shaft by hand. You should see QH toggle between two values. Based on the two numbers rewire the motor power leads, leaving the hall sensors untouched. (or vice-versa, which ever is easier).

QH Numbers	Action Required
1 3	None - Wiring is correct
3 2	Swap B and C
2 6	Move B to C, C to A, A to B
6 4	Swap A and B
4 5	Move B to A, A to C, C to B
5 1	Swap A and C

7. Verify that QH now wiggles between 1 and 3. *Note – If Method #1 doesn't return 1 and 3 after the first try then you probably have inverted halls. Use Method #2 instead.*
8. Now check that TP is less when QH1 then QH3. (If using GalilTools add \_TP to Watch Window). If TP is not less at QH1 then QH3 you will have positive feedback and the motor will run away. To fix this
  - a. If using differential encoder, swap A- and A+ wires
  - b. If using single ended encoder, swap A and B wires
  - c. If you prefer to keep the encoder direction the same and instead want to change the motor polarity please see *Reversing Motor Polarity* at the end of this note.
9. Now set OF back to 0 (OFX=0) and put the amplifier back in brushless mode (BRX=0). Set small values of KP and KD and verify the motor holds position. The motor is now under closed loop control.
10. Issue a small jog command (JGX=1000;BGX) and verify the motor spins smoothly. The QH sequence should be 1,3,2,6,4,5. If working properly, you may now proceed to tuning.

## **Method #2 – Trying Each Combination**

A majority of motors can be properly wired using Method #1 above however some motors will not work with that method. The more complete method is to try each of the 6 wiring combinations and check the velocity in each case. Note that some of the wiring combinations will lead to no motion. This is ok – simply move to the next combination.

1. Wire the 3 motor phase wires and 3 hall sensors randomly. Do not connect the motor to the load yet. A free spinning motor is recommended for testing.
2. Set the PID's and BR to zero (KPX=0;KDX=0;KIX=0;BRX=0)
3. Issue a small offset with the OF command (ex OFX=.5). This will cause the motor to free spin. The smallest OF possible to see motion is recommended.
4. Check the velocity of the motor with the TV command (can also be displayed in GalilTools Watch Window). Record this value in either Table 1 or Table 2 below.
5. Issue an equal but opposite OF. For example, if you previously issued OFX=.5 now issue OFX=-.5. Again record the velocity below
6. Now issue OFX=0. Power down the system and swap 2 wires in the hall sensors or motor power leads. Pick one or the other, but do not swap both.
7. Repeat steps 2-6 for each of the six combinations until one of the tables below is completely filled out.
8. The correct wiring will be the one that has the magnitude of the velocity in the positive direction the closest to the magnitude of the velocity in the negative direction. In the case that there are two combinations that are both similar, choose the wiring that has the higher velocities. In the example below Trial 1 would be the correct choice

<u>Trial #</u>	<u>Phase A</u>	<u>Phase B</u>	<u>Phase C</u>	<u>+ Velocity</u>	<u>- Velocity</u>
1	Power lead 1	Power lead 2	Power lead 3	153700	-160000
2	Power lead 1	Power lead 3	Power lead 2	0	0
3	Power lead 2	Power lead 3	Power lead 1	0	0
4	Power lead 2	Power lead 1	Power lead 3	-141000	139000
5	Power lead 3	Power lead 1	Power lead 2	0	0
6	Power lead 3	Power lead 2	Power lead 1	-70000	92000

9. Now check that TP is less when QH1 then QH3. (If using GalilTools add \_TP to Watch Window). If TP is not less at QH1 then QH3 you will have positive feedback and the motor will run away. To fix this
  - a. If using differential encoder, swap A- and A+ wires
  - b. If using single ended encoder, swap A and B wires
10. Now set OF back to 0 (OFX=0). Set small values of KP and KD and verify the motor holds position. The motor is now under closed loop control.
11. Issue a small jog command (JGX=1000;BGX) and verify the motor spins smoothly. The QH sequence should be 1,3,2,6,4,5. If working properly, you may now proceed to tuning.

<u>Trial #</u>	<u>Phase A</u>	<u>Phase B</u>	<u>Phase C</u>	<u>+ Velocity</u>	<u>- Velocity</u>
1	Power lead 1	Power lead 2	Power lead 3		
2	Power lead 1	Power lead 3	Power lead 2		
3	Power lead 2	Power lead 3	Power lead 1		
4	Power lead 2	Power lead 1	Power lead 3		
5	Power lead 3	Power lead 1	Power lead 2		
6	Power lead 3	Power lead 2	Power lead 1		

**Table 1 – Changing Power Leads (Hall Sensors Fixed)**

<u>Trial #</u>	<u>Hall A Input</u>	<u>Hall B Input</u>	<u>Hall C Input</u>	<u>+ Velocity</u>	<u>- Velocity</u>
1	Motor Hall 1	Motor Hall 2	Motor Hall 3		
2	Motor Hall 1	Motor Hall 3	Motor Hall 2		
3	Motor Hall 2	Motor Hall 3	Motor Hall 1		
4	Motor Hall 2	Motor Hall 1	Motor Hall 3		
5	Motor Hall 3	Motor Hall 1	Motor Hall 2		
6	Motor Hall 3	Motor Hall 2	Motor Hall 1		

**Table 2 - Changing Hall Sensors (Power Leads Fixed)**

*Use Table 1 or Table 2 – Not both.*

### **Reversing Motor Polarity**

Once proper commutation has been found you may find that the motor runs away after an SH is given. To fix this you can change the motor direction by swapping **Hall A and B** and also **Motor B and C**.