AN186
Brushless DC (BLDC) Motor Connections

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BRUSHLESS DC (BLDC) MOTOR CONNECTIONS

Because there are no established standards regarding the wiring of brushless DC (BLDC) motors and controllers, Hall sensors and phase leads may be labeled ABC, UVW, or they may not labeled at all. It is often easier to figure out the correct connection using trial and error rather than trying to analyze the motor to understand its phasing.

The three Hall sensors can be arbitrarily connected, and there are six possible methods to connect the motor phase leads (see Table 1).

Table 1: Motor Phase Lead Configurations

Configuration 1	A-B-C
Configuration 2	C-A-B
Configuration 3	B-C-A
Configuration 4	B-A-C
Configuration 5	C-B-A
Configuration 6	A-C-B

Of these six phase wiring combinations, only one connection is correct; meanwhile three connections completely prevent the motor from rotating. The remaining two incorrect connections deserve particular attention. If the motor is wired in one of these two configurations, the motor turns but its performance is severely impaired.

Three key factors determine whether the motor is wired improperly: torque, torque ripple, and directionality. The torque of the two poorly performing configurations is significantly lower than a properly wired motor's torque. Torque ripple is also very pronounced as the motor turns. Finally, the motor may run differently when rotating in one direction than the other direction, depending on the connection.

Finding the three wiring configurations that enable the motor to turn is the easiest way to determine whether the motor is wired correctly. Compare the motor's operation in each configuration. The proper configuration has the most torque and the lowest current consumption. To find the proper wire configuration, follow the steps below:

1. Arbitrarily assign numbers to the motor's three Hall output wires, then connect them to the three Hall sensor inputs on the evaluation board.
2. Connect the Hall sensors' supply voltage and ground to a power supply.
3. Arbitrarily assign letters (i.e. A, B, and C) to the motor's phase wires, then connect them to the evaluation board's three phase outputs.
4. Apply power to the evaluation board and enable the motor. If the motor turns, find the optimal phase wiring configuration by following the steps below:
    a. Move each phase wire over one position (for example, A, B, and C then becomes C, A, and B), then compare the torque and torque ripple between each configuration.
    b. Move each phase wire over one position further (C, A, and B then becomes B, C, and A), then compare the torque and torque ripple.
    c. Use the wiring configuration that gives the highest torque and lowest torque ripple.
5. If the motor does not turn, exchange any two of the phase wires until the motor rotates.
6. Return to step 3 to compare the three wiring configurations that make the motor turn, and select the configuration with the highest torque and the lowest current consumption.
7. If the motor turns opposite of the desired direction, exchange the two Hall input wires, then repeat steps 3 and 4.

Additionally, once the motor is spinning, the phase voltages (and optionally, the phase current) can be observed with an oscilloscope to see if it is connected correctly. If the connection is correct, the phase voltage waveforms are approximately symmetrical (see Figure 1).

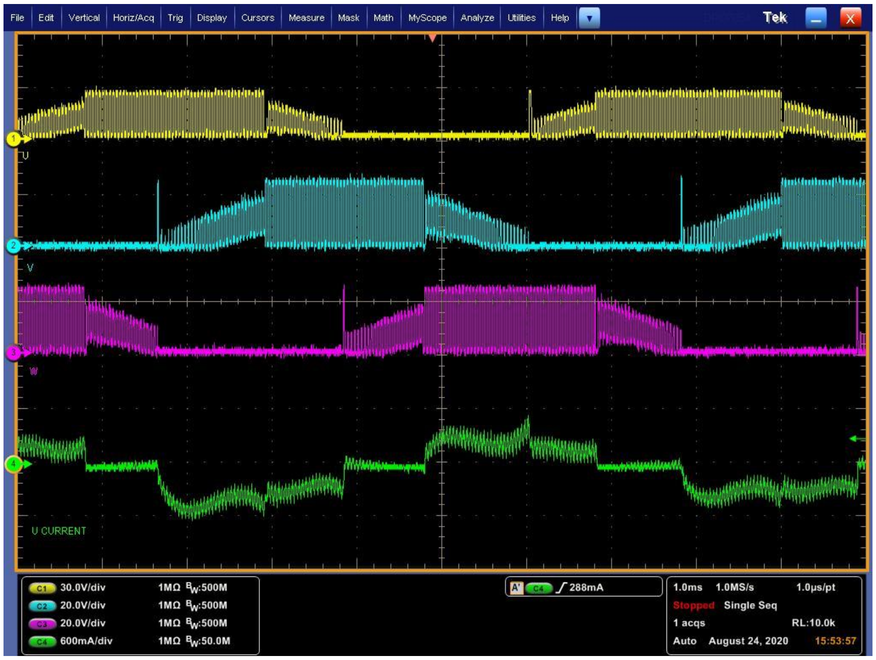

Figure 1: Phase Voltage Waveforms with Proper Wiring Configuration

If the phases are incorrectly connected, the shoulders of the waveforms where the phase is in a high-impedance, zero current state look very different.

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	4/4/2022	Initial Release	-