Rotor Position Sensor Design For a 2-Pole BLDC Motor Controller

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Introduction

This project is meant to introduce the concept of the switching mechanisms controlled by hall effect sensors for a BLDC motor. BLDC motors are able to control their PWM triggers with a timed algorithm, yet that is not the most effective way to control them. The biggest flaw in the timing-based PWM inverter signals is that the user has no way to accurately know the position of the rotor. This can be solved with cleverly placed hall effect sensors placed around the rotor.

Hall effect outputs an electrical signal when in the presence of a magnetic field, which can then be used to control transistors, LEDs, or other electrical loads. This can be seen in *Figure 1.* This principle works perfectly for detecting the rotor position for a BLDC as the rotor is made of permanent magnets and will be able to trigger the Hall Effect sensor when the magnetic field of the rotor is applied.

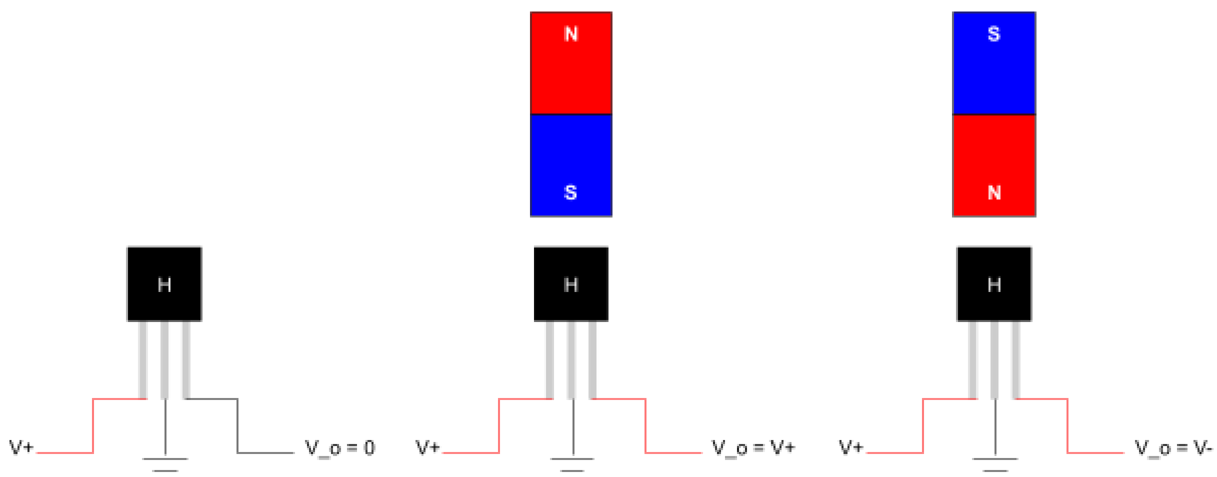


Figure 1: Hall Effect Sensor under no magnetic field vs. magnetic stimuli

Hall Sensor Design

Design: Two hall effect sensors will be placed at 180° and 270° respectively. This is the perfect area to place the hall effect sensors, as the stator flux can lead by 90° every switch, generating the highest amount of torque possible.

Diagram:

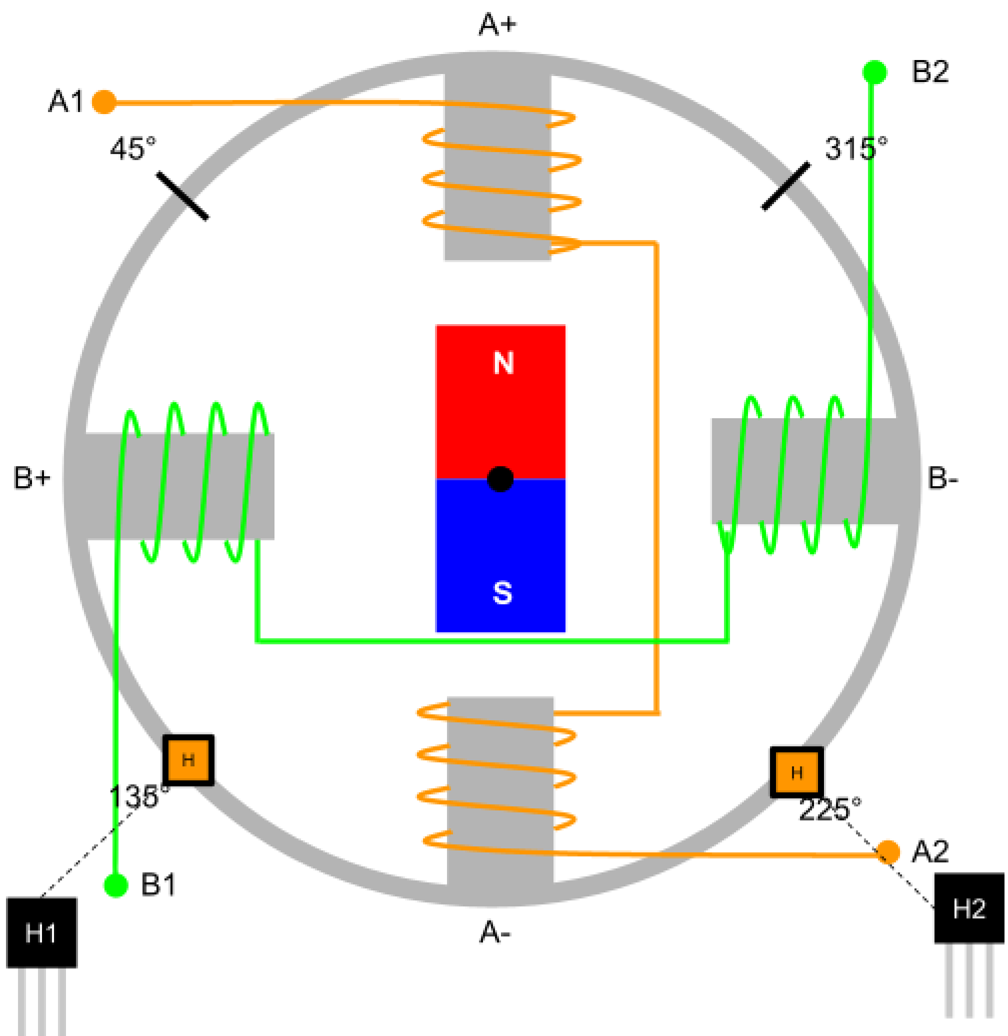


Figure 2. Proposed Hall sensor placement

Description: I was originally contemplating adding 4 hall sensors to the design, in between each of the coils, but realized that I could cut that number in half as the hall effect sensor would be able to tell if the magnetic field is north or south with difference in voltage output. The hall effect sensors go 90 degrees from each other as the stator flux has to lead the rotor flux by 90 degrees for best torque generation, making it the perfect time to switch h-bridge gates on the coils.

System Block Diagram

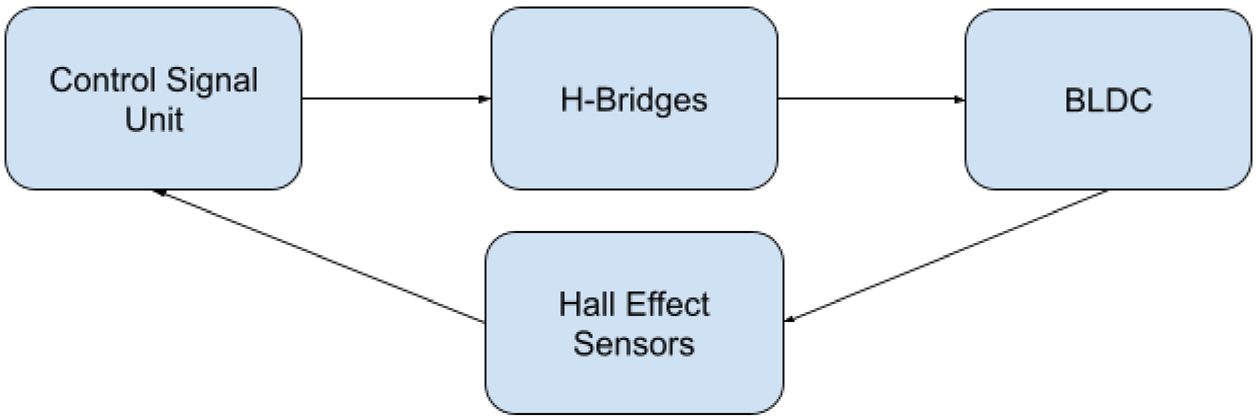


Figure 3. System Block Diagram

Power Electronics

Design: This is the design of the two H-bridge circuits that the hall effect sensors will be connected to. The control signal unit will be used to control the power electronics unit. One of the H-bridge circuits will be dedicated to the A coil pair, and the other will be dedicated to the B coil pair. When transistors 1&4 are on, the A coils are energized positively. When transistors 2&3 are on, the A coils are energized negatively. When transistors 1&4 are on, the A coils are energized positively. When transistors 2&3 are on, the A coils are energized negatively.

Diagram:

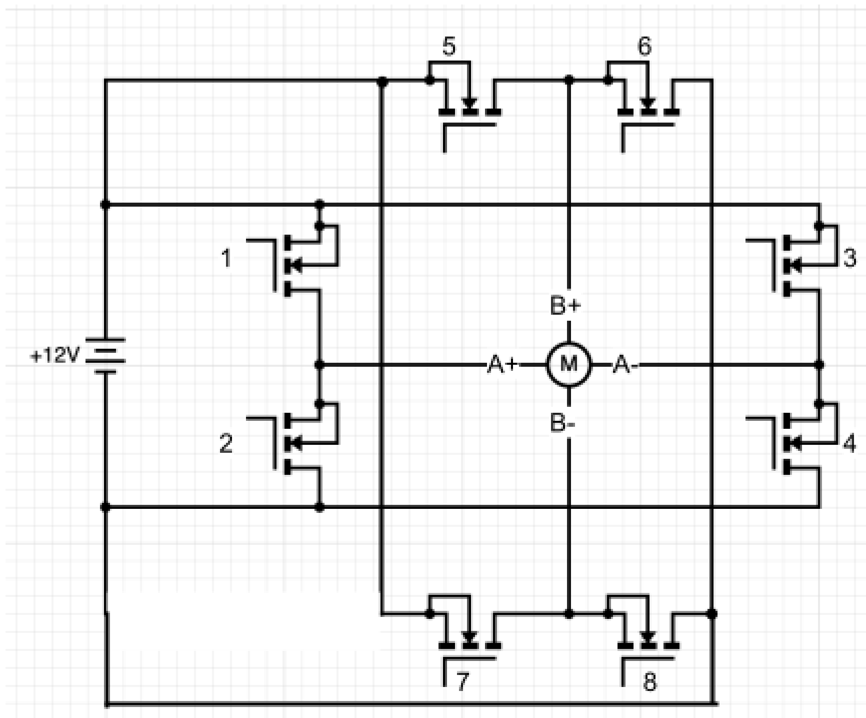


Figure 4. Power electronics circuit design

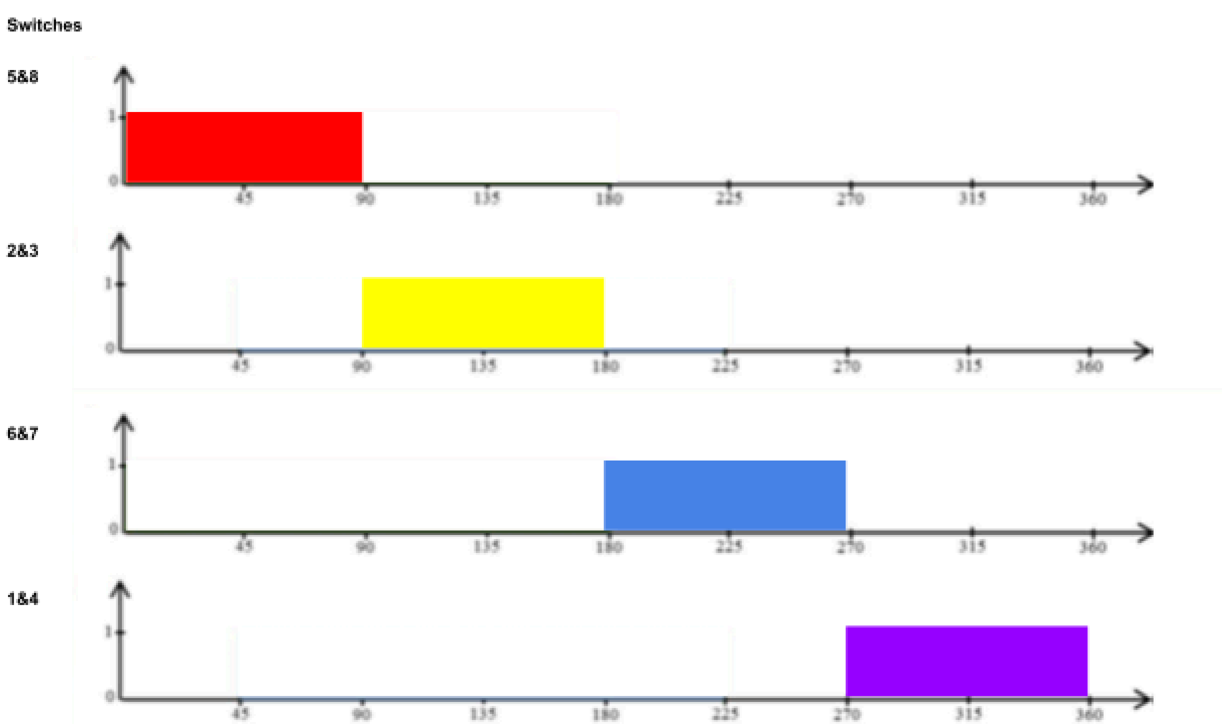


Figure 5. Switch timing diagram

Description: The switches will be energized for 90°, then turned off when the magnet pole combination of the hall effect sensors switch. The switches will be switched whenever they are ~90° from the next coil as we want to produce the best torque generation.

Digital Logic

Logic diagram:

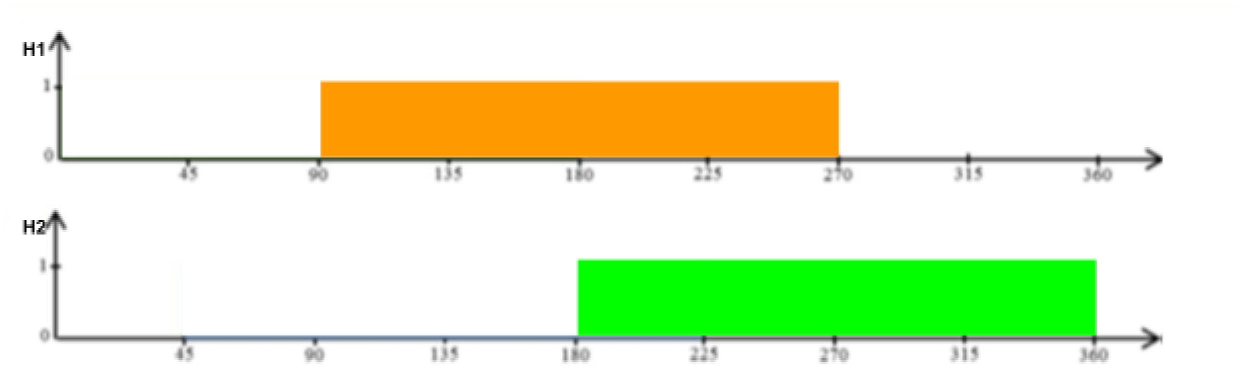


Figure 6. Hall Sensor timing diagram

Step	**Switch on**	**Rotor Position (°)**
Counter-Clockwise		
1	5&8	0-90
2	2&3	90-180
3	6&7	180-270
4	1&4	270-360

Table 1. Step operation of the machine

Truth tables:

Coil Energized	Step 1	Step 2	Step 3	Step 4

A+	0	0	0	1
B+	1	0	0	0
A-	0	1	0	0
B-	0	0	1	0
Hall Sensor				
H1	0	1	1	0
H2	0	0	1	1

Table 2. Truth table design of the machine

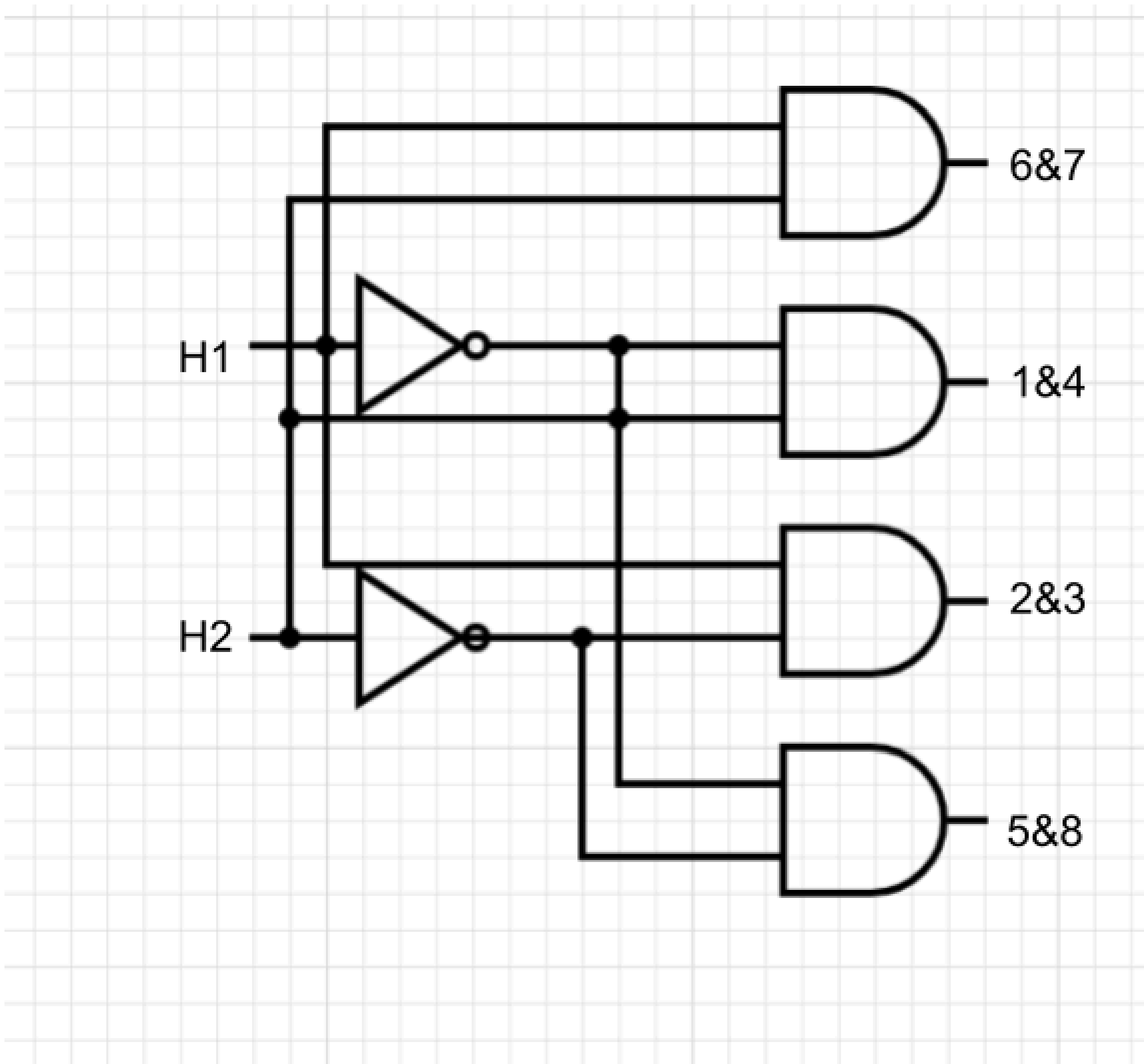


Figure 7. Final logic circuit

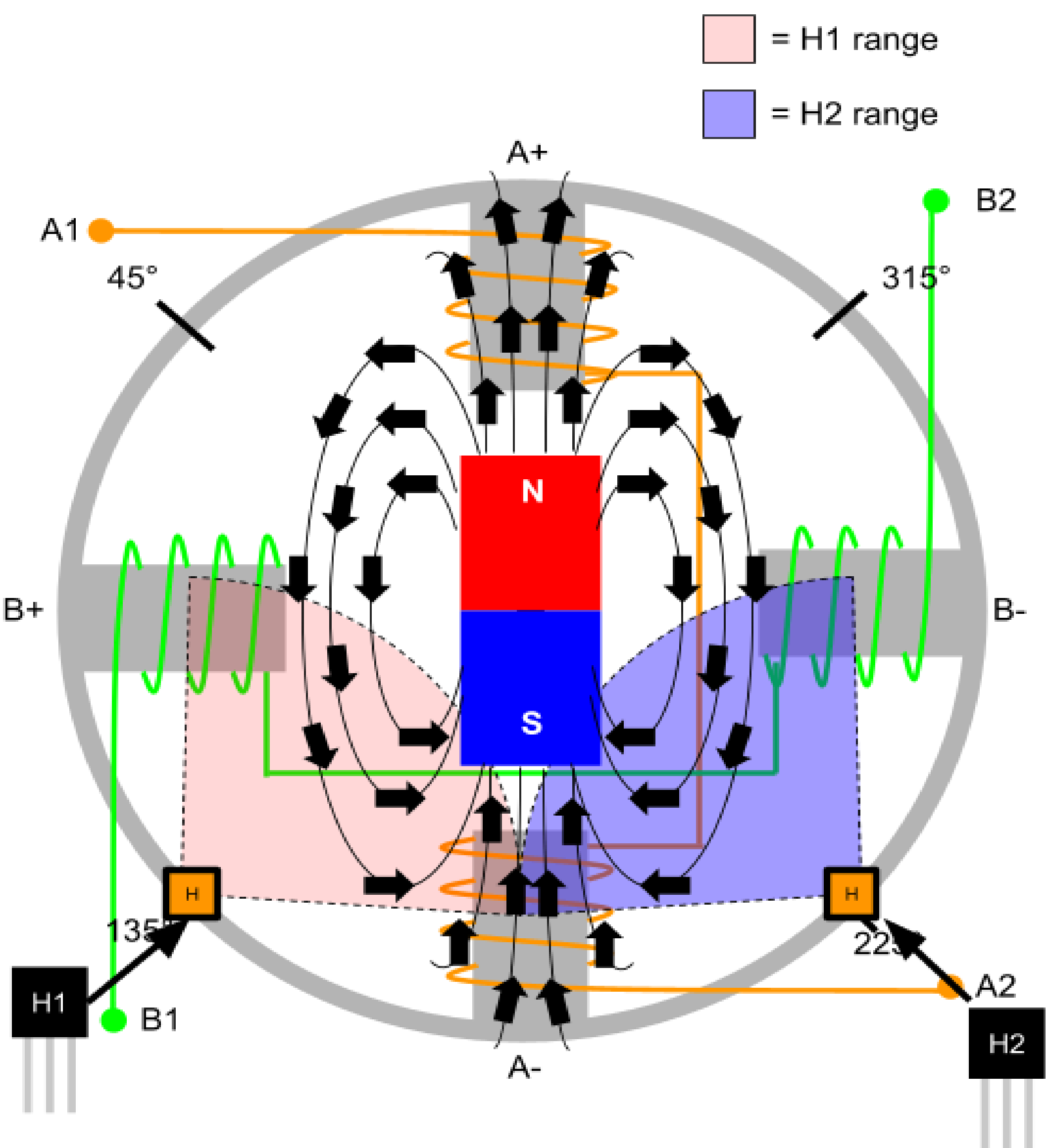


Figure 8. Diagram showing Regions where each hall signal will detect a "North" signal

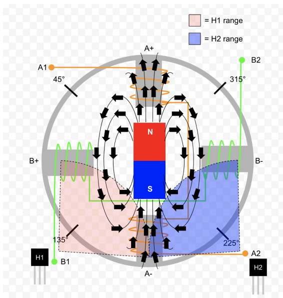
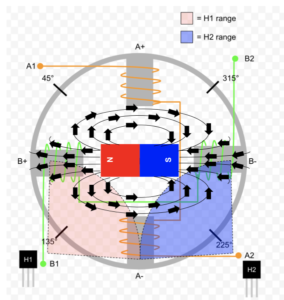
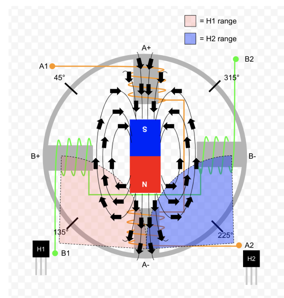
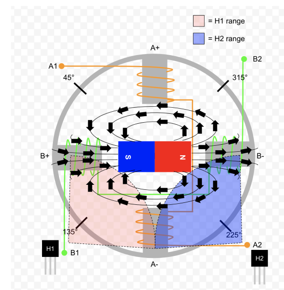
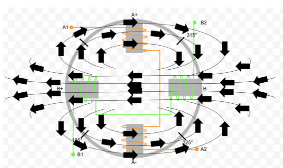
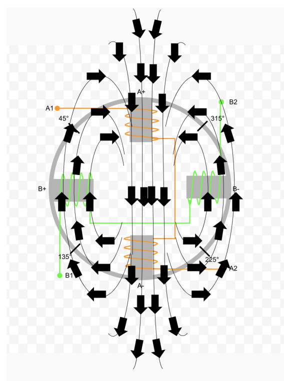
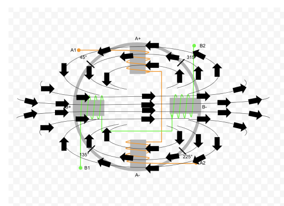
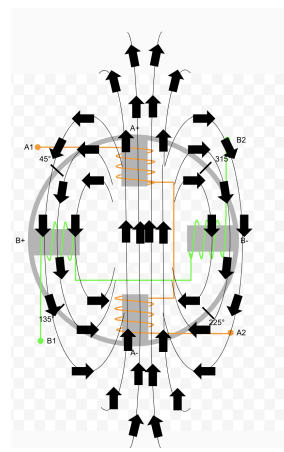
Position 1	Position 2	Position 3	Position 4
Hall 1: 0 Hall 2: 0	Hall 1: 1 Hall 2: 0	Hall 1: 1 Hall 2: 1	Hall 1: 0 Hall 2: 1
			
			

Table 3: Different positions of rotor flux vs winding flux for 1 rotation cycle

Description: The hall sensor will mainly detect a "North" signal input from the rotor for 180° of the circuit, and will detect a "South" signal input for the other 180° of the circuit. "North" will be used for 1 and "South" will be used for 0. We want the energized coil to change when it is near the coils, so for this we chose a 90° rotational offset for the hall sensors. When the hall sensors *both* detect a "north" or "south" signal, the magnet poles are between the hall sensors. The other times where the Hall sensor will detect a "South" signal is demonstrated in *Figure 8.* The logic that we use to switch the circuit on and off is detailed in *Figures 5-7* and *Tables 1-2* above.

Summary and Conclusion

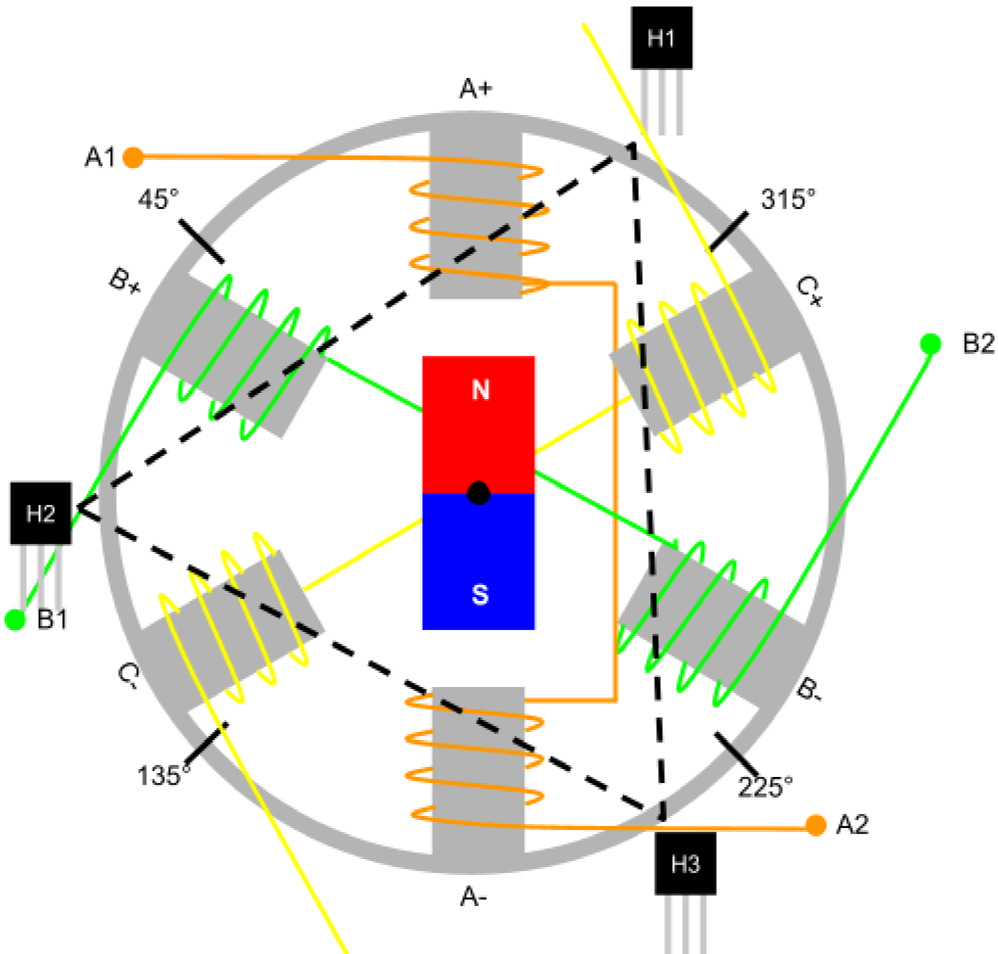


Figure 10: positioning of hall sensors for rotor position detector of 3-phase BLDC

For a BLDC motor, 2 hall sensors placed at a 90° offset is the best way to provide rotor position with digital logic, and 2 H-bridges are necessary to correctly energize the two coil pairs independently. The 2 hall sensors allow for 4 states, where the flux of the stator leads the flux of the rotor by 90° for high torque generation. This same principle would apply for a 3-phase BLDC motor, but instead of a 90° offset for the hall sensors, it would require a 120° offset to determine rotor positioning as shown in *Figure 9*. The 120° offset would also have the necessary states to operate the h-bridges of a BLDC motor with 3 coil pairs. For a 3-phase DC motor, only one rotor magnet is necessary, but 3 coil pairs are necessary as well. Timing for the BLDC motor may not always work, so positioning sensors are vital for reliable operation.