EXPERIMENT- 5
Understanding and Operation of BLDC Motor

1. Aim:

1. Familiarisation with Brushless DC (BLDC) motor.
2. Familiarisation with Back EMF waveform.
3. To understand the hall sensor output sequence.
4. To determine the torque-speed characteristic of BLDC motor drive.
5. Familiarisation with digital storage oscilloscope.
6. Familiarisation with differential probe and passive probe.

2. Theory:

References:

1. https://www.renesas.com/en/support/engineer-school/brushless-dc-motor-01-overview
2. https://youtube.com/playlist?list=PLn8PRpmsu08p5OFWiVlNk-w0Xn4j0dT_l&si=YuESLQ4MLg_vbpLJ
3. https://www.ti.com/lit/ug/tiduay9/tiduay9.pdf

3. Precaution:

- Voltage applied to the BLDC motor controller should not exceed 54 V.
- Input current to the BLDC motor should not exceed 16 A.
- Always connect the rheostat across the DC link capacitor to prevent damage to the power electronic converter.
- Gradually change the throttle so that the speed of the BLDC motor does not exceed 1800rpm.
- Don't touch the DC link capacitor immediately after switching off the motor.
- The phase voltage wires of the BLDC motor and the controller should be connected properly according to the colour code.

4. Procedure:

There are three machines mounted on the stand, two of which are DC machines, and one is BLDC Motor. Note the nameplate ratings of these machines and use one of them as a DC motor and the other as a separately excited DC generator. The nameplate ratings are:

- 1kW BLDC motor: 48V, 20A, 1600rpm
- 1.5kW DC machine (DC motor): 180v, 10.5A, 1500rpm
- 1.1kW DC machine (DC generator): 180v, 7.5A, 1500rpm

4.1 Familiarisation with back EMF waveform:

A. Connect the circuit as shown in Fig1. In this experiment, the DC motor will be used as a prime mover for the BLDC motor.
B. Connect the motor's phase wire (U, V, W) to the star-connected bulb load(60w/100w) A, B, and C terminals to realize the virtual neutral.
C. Connect the DC motor controller and operate the motor at 1500rpm.
D. Observe the phase voltage of the star-connected bulb load using an oscilloscope. The back EMF should appear as a trapezoidal waveform (in the case of phase voltage). Why?
E. Observe the magnitude of the waveform while varying the speed of the DC motor.

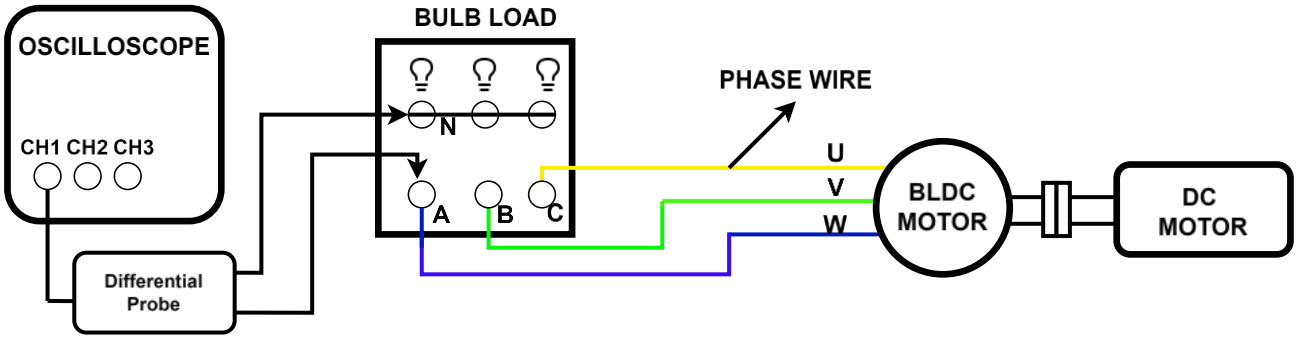


Fig1: - Circuit diagram for back emf waveform setup

4.2 Familiarisation of the hall sensor output sequence:

A. Connect the circuit as shown in Fig2. The DC motor will be used as a prime mover for the BLDC motor.
B. The back emf connection should be intact while doing this part of experiment.
C. Connect the 5v pull-up resistor to the hall sensor output pin from the BLDC motor.
D. Use regulated DC power supply to 5v pull-up resistor (10kΩ).
E. Connect the DC motor controller and operate the motor at 1500rpm.
F. Connect the oscilloscope across the pull-up resistor by using the non-isolated probe. The differential probe should also connect to show the backemf waveform.
G. Observe the signals from the Hall sensors in the oscilloscope.

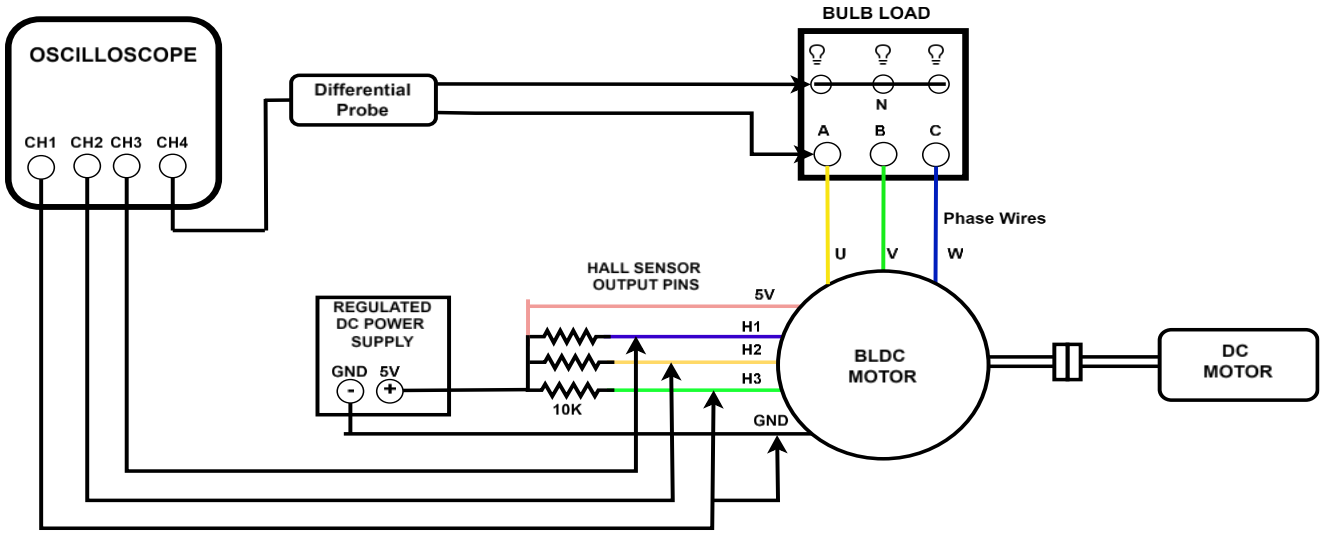


Fig2: - Circuit diagram of hall sensor output sequence setup

4.3 To draw torque-speed characteristic of BLDC motor drive:

A. Connect the circuit as shown in Fig3. The circuit consists of a 3-phase autotransformer, 3-phase rectifier, BLDC controller, BLDC motor, and DC generator as a load.
B. The BLDC motor controller is connected to a 3-phase rectifier. The throttle is connected to the BLDC motor controller. The hall sensor output pins and phase wire are connected to the controller.
C. Initially, the autotransformer should be at the 0th position and then increase the voltage to desirable voltages. Gradually increase the throttle to set the speed at 1500rpm. The experiment should be done in two parts at different DC link voltages (48v,50v, and 52v).
    1) Set the DC link voltage at 48v,50v and 52v. Ignore the drop in DC link voltage when the machine is loaded.
    2) Set the DC link voltage at 48v,50v and 52v. The DC link voltage should be kept constant when the machine is loaded, with the help of autotransformer.
D. Load the BLDC motor using DC generator. Note the output of the DC generator and then use it to find the power output of the BLDC motor with the help of the efficiency curve of the DC generator.
E. Gradually increase the load on the BLDC motor and measure the speed with the help of a tachometer. Then, calculate the torque of the BLDC motor.
F. Plot the torque-speed characteristic using calculated data.

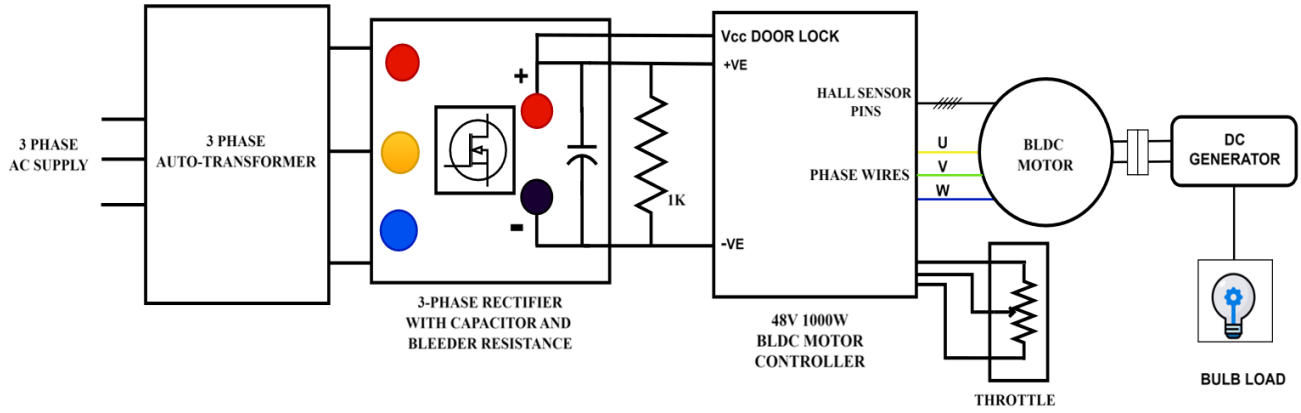


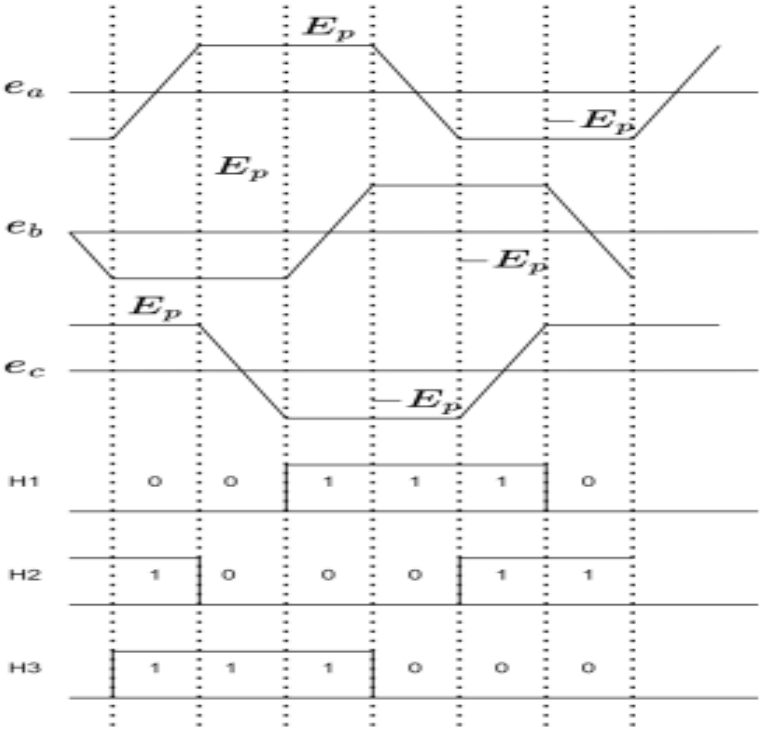
Fig3: Circuit diagram of BLDC Motor drive setup

5. Question to be answered

- What is the difference between a BLDC motor and a DC motor?
- Why does the BLDC motor have a higher torque-to-weight ratio than the DC motor?
- What is the difference between a Brushless DC motor and a Permanent Magnet Synchronous Motor?
- How accurately can the hall sensor determine the rotor position?
- What are the applications of BLDC motors?
- What are the probes we are using and why they are different?

6. Post lab Activity:

- The student should plot the torque-speed characteristics and write the conclusion.
- The Back emf and hall sensor output is as follows. The student will determine the phase to be excited in the BLDC motor by using this emf and hall sensor output.



Hall Sensor Output (H1 H2 H3)	Phases to be energised
011	
001	
101	
100	
110	
010	