Design And Implementation of Three Phase Motor Driver For PWM-Based BLDC Motor Speed Control

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Abstract. The Along with the times, the need for motors that have high efficiency, high torque, high and variable speed, and low maintenance costs has increased. one of these motors is a Brushless DC motor that uses electric commutation so that it has high efficiency and long operating time. Therefore, to meet the need for high efficiency, high torque, high and variable speed, and low maintenance costs, a Brushless DC motor (BLDC) or a Brushless AC motor (BLAC) is used. BLDC motors are widely used in industry compared to other types of motors, because BLDC motors have many advantages. But there is also a weakness of the BLDC motor, namely the difficulty in regulating the speed. With this condition the author is interested in making an innovation to overcome this problem, by making a three-phase motor driver as a BLDC motor control to regulate the rotation of the BLDC motor so that the speed can be varied. This three-phase motor driver consists of an Arduino Nano microcontroller and a three-phase inverter circuit that uses an IRF3205 MOSFET. The Arduino Nano microcontroller is used as a MOSFET ignition in a three-phase inverter circuit, the result is The success parameter of this research is being able to determine the commutation of the BLDC motor which is then controlled by a three-phase inverter through the Arduino NANO microcontroller to control the speed of the BLDC motor with a certain frequency.

Keywords: Brushless DC Motor, Arduino NANO, 3 Phase Inverter, Hall Effect Sensor, MOSFET IRF 3505.

1 Introduction

Along with the times, the need for motors that have high efficiency, high torque, high speed and can be varied, and low maintenance costs is increasing. These weaknesses can be overcome by using a Brushless DC motor that uses electric commutation so that it has high efficiency and long operating time [1]–[3]. Therefore, to meet the need for high efficiency, high torque, high and variable speed, and low maintenance costs, a Brushless DC motor (BLDC) or a BrushlesS AC motor (BLAC) is used. In order for the BLDC motor to work, it is necessary to have a rotating magnetic field in the stator [4]–[6]. To obtain the rotating magnetic field of the stator, a 3-phase ac voltage source is needed on the motor stator. Therefore, a 3-phase inverter is used to convert the DC voltage into a 3-phase ac voltage. Based

ICSEDTI 2022, October 11-13, Tanjungpinang, Indonesia

DOI 10.4108/eai.11-10-2022.2326430

on the form of 3-phase ac voltage generated by the inverter, there are 2 methods used in controlling the BLDC motor inverter, namely by using the sinusoidal Pulse Width Modulation (PWM) method and the six-step method [7]–[9]. The six-step method is a method that is often used in controlling BLDC motors. This happens because this method is easy to implement and has a simple algorithm. The waves generated from this method are square or trapezoidal.

1.1 Brushless DC Motor

Brushless DC motor or also known as electronically commutated motor (electric commutated motor) is a type of synchronous motor that is supplied by a DC power source to operate its control and has an electrical commutation system. In general, BLDC consists of two parts, namely the rotor, the moving part, which is made of permanent magnets and the stator, the stationary part, which is made of 3-phase coils. Although it is a 3-phase AC synchronous electric motor, this motor is still called a BLDC because in its implementation BLDC uses a DC source as the main energy source which is then converted into AC voltage using a 3-phase inverter. The purpose of applying a 3-phase AC voltage to the BLDC stator is to create a rotating magnetic field of the stator to attract the rotor magnets [10]–[12].

Because there are no brushes on the BLDC motor, to determine the right commutation timing on this motor so that a constant torque and speed is obtained, 3 Hall sensors and an encoder are needed. In the Hall sensor, the commutation timing is determined by detecting the magnetic field of the rotor using 3 Hall sensors to get 6 different timing combinations.

1.2 Hall Effect Sensor

Hall Effect Sensor is a transducer that can convert magnetic information into electrical signals for further processing of electronic circuits. This Hall Effect sensor is often used as a sensor to detect proximity (proximity), detect position (positioning), detect speed (speed), detect movement direction (directional) and detect electric current (current sensing) [13]–[15]. A transducer that varies its output voltage in response to a magnetic field. Hall sensors are usually used for timing wheel and axle speed, such as for internal combustion engines with ignition timing, tachometers and anti-lock braking systems. In brushless DC electric motors there is a Hall sensor to detect the position of the permanent magnet contained in the motor which will send signal to the microcontroller to provide a switching signal for the mosfet so that it can rotate the BLDC motor. In the BLDC motor itself, there are 3 hall sensors with different angles of 120 degrees so that they can form 6 combinations.

1.3 Three Phase Inverter

Inverter is a converter to convert DC voltage into AC output voltage whose frequency can be adjusted. The output variable voltage can be set by setting the input voltage. If the input voltage is constant, then we can adjust the output voltage by adjusting the gain of the inverter which is usually done with PWM control[16], [17]. To be able to carry out the Six-Step steps, a 3-Phase Driver consisting of six MOSFETs is needed as shown in Figure 1.

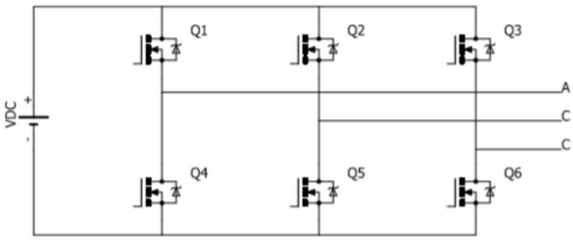

Fig. 1. 3-Phase Inverter

MOSFETs Q1, Q2, Q3, Q4, Q5 and Q6 (usually using MOSFETs) are controlled following a periodic sequence of 6 states.

Table 1. The sequence of steps so that the motor rotates clockwise (CW).

Time (Step)	Hall Input			Phase A		Phase B		Phase C	
	A	B	C	Q1	Q2	Q3	Q4	Q5	Q6
1	0	0	1	0	0	0	1	1	0
2	1	0	1	1	0	0	1	0	0
3	1	0	0	1	0	0	0	0	1
4	1	1	0	0	0	1	0	0	1
5	0	1	0	0	1	1	0	0	0
6	0	1	1	0	1	0	0	1	0

In this design, N channel MOSFET is used as a switch. MOSFETs have smaller power losses due to the switching process compared to other types of transistors. The MOSFET used in this final project is a MOSFET of the IRF3250 type. MOSFET type IRF3205 is an NPN type transistor capable of working up to 110A. Since the IRF3205 has a maximum current of up to 110A, some MOSFETs may be subject to PWM signals. The use of PWM on transistors can increase a transistor stress.

2. BLDC Motor Simulation using Proteus

This paper discusses the simulation results of a BLDC motor using Proteus software. This simulation is carried out when designing the tool or before making the tool, it is useful to find out the results needed as an illustration of the real results of making the tool.

The implementation of the tool uses a 3-phase inverter to control the BLDC motor using a digital control system in the form of an Arduino NANO microcontroller. Next, we will discuss the simulation of the implementation of using a 3-phase inverter to control a BLDC motor using the Proteus software.

At the time of designing the tool the author needs an overview of the final result of making the tool in the form of the BLDC motor [18], [19]. Therefore, the author uses Proteus software to perform the necessary simulations to see an overview of the final result. The following describes the system circuit of the BLDC simulated with Proteus in the Figure 2 & 3.

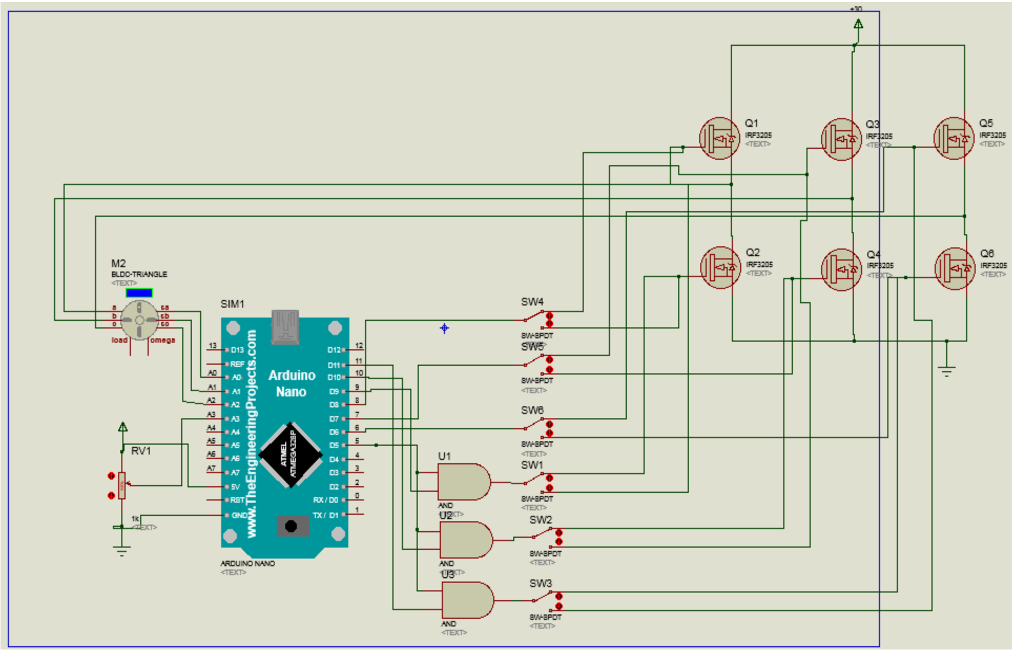

Fig. 2. BLDC Simulation Control Using Proteus

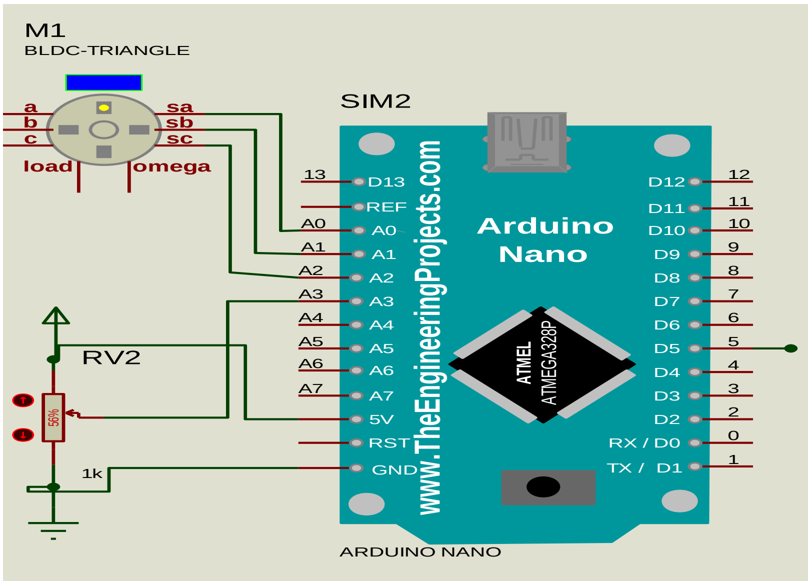

Fig. 3. Port positioning for BLDC motor and Potentiometer

Based on Figure 2, - 3, it is explained that the minimum system circuit gets an input signal in the form of an ADC input on Pin PC0 and input from the hall effect sensor readings on the rotor position with the following mechanism [15]: H1 on pin A0, H2 on pin A1, and H3 on pin A2. The output signal generated by the Arduino NANO microcontroller will be issued by the output side on PA3 as a set duty cycle and PD10, PD9, PD8, PD7, PD6, PD5 as a PWM set. Before it will be an input signal for the TTL 7408 IC which will produce an output in the form of a switching PWM. The TTL 7408 IC requires a 5 Volt supply voltage.

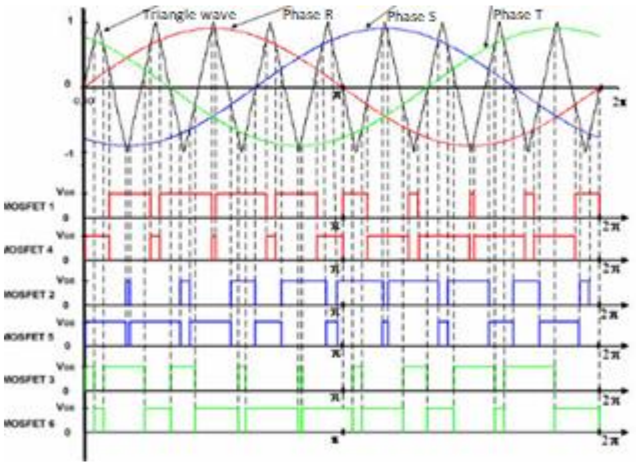

Figure 4. PWM generator wave

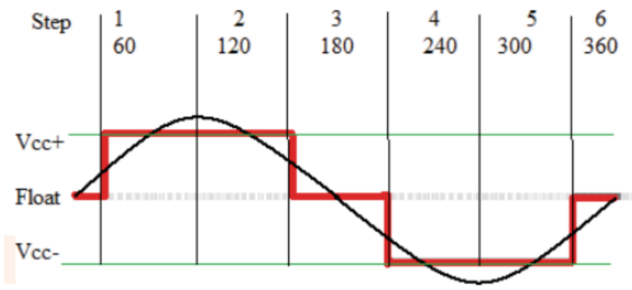

Figure 5. Six-step method

In BLDC motor construction there is a hall effect sensor to read the magnetic field from the coil that passes through it [17]. This hall effect sensor then gives a data signal back to the microcontroller. Based on this signal data, the microcontroller can determine the commutation position of the motor (Figures 4 and 5).

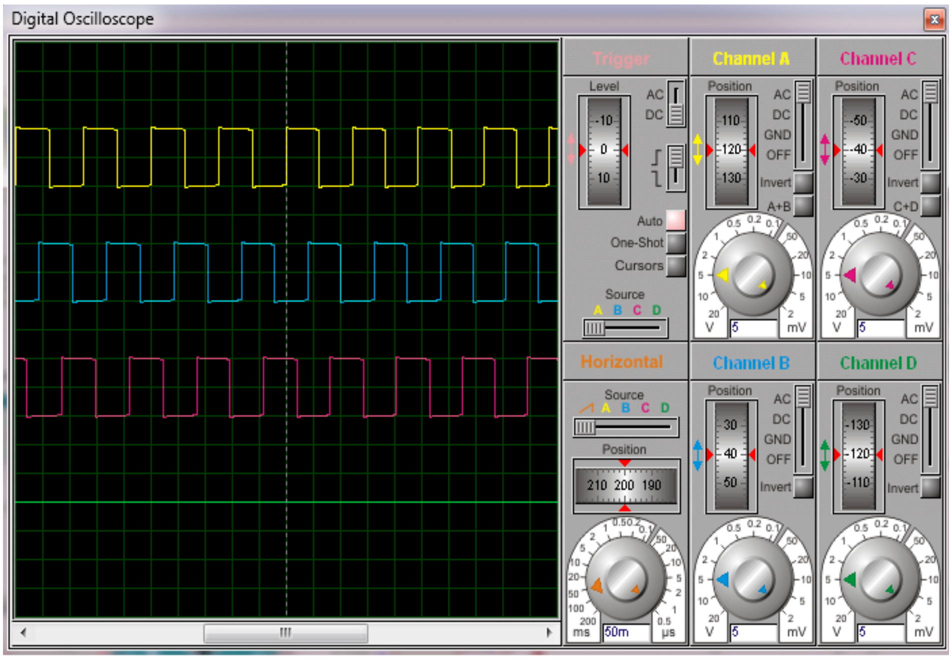

Fig. 6 = Hall Sensors A, B, and C Clockwise.

While Figure 6, it can be seen that the resulting PWM resolution is very dependent on the triangular signal frequency used. The greater the frequency of the triangular signal used, the better the resulting PWM resolution. And the higher the PWM resolution used, the more perfect sinusoidal waves are formed. Due to the complexity of the operations used and the large number of microcontroller resources to form a sinusoidal PWM, table-lookup is used. This table contains the sinusoidal PWM signal timings that have been formed from the comparison of the two signals so that the complexity of mathematical operations can be avoided [17].

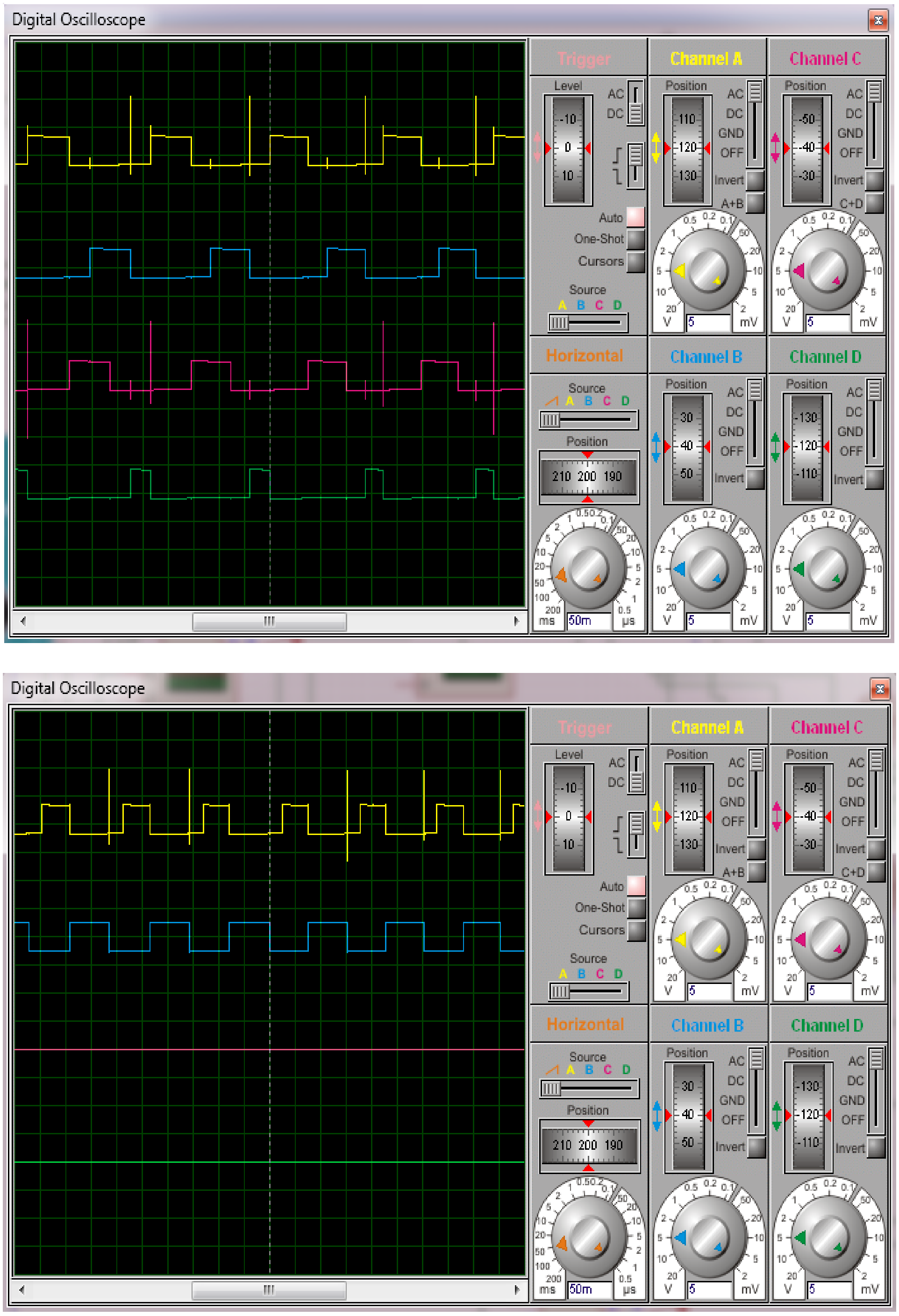

Fig. 7=. Clockwise (CW) Switching MOSFET.

In the MOSFET switching simulation experiment in a clockwise direction (Figure 7), there is still ripple in the wave which causes the motor to experience vibration which will damage the motor and then the pulse width is not nearly the same as the others, this affects the speed of the BLDC motor. The concept that must be remembered in BLDC motor drivers is that by adjusting the width of the positive and negative sides of the pulse at a frequency that remains constant. The duty cycle setting determines the amount of power that enters the motor.

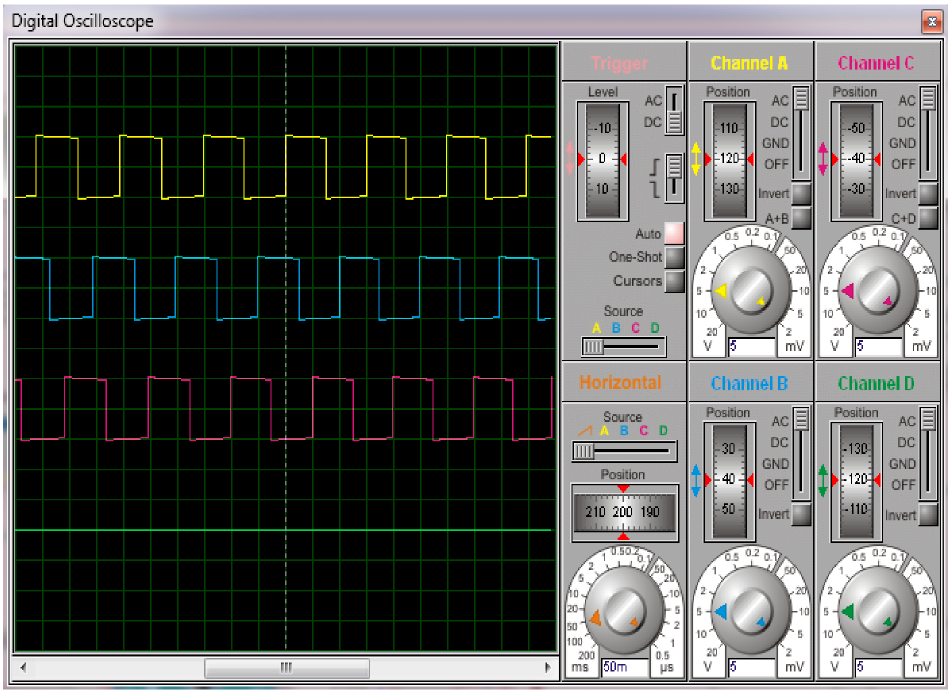

Fig. 8=6. Hall Sensors A, B and C Counter clockwise (CCW)

In Figures 8 and 9 the simulation results above show that there are no defects in the waves so that the motor speed is not disturbed by ripples. The shape of the duty cycle changes in width almost the same, this indicates that the motor speed is constant and runs smoothly, to find the value of the PWM it is necessary to calculate between the High period and the Low period. With the Duty Cycle formula = tON / (tON + tOFF). Where the duty cycle is the ratio between the high period and the low period in the PWM voltage. tON is the high period and tOFF is the low period.

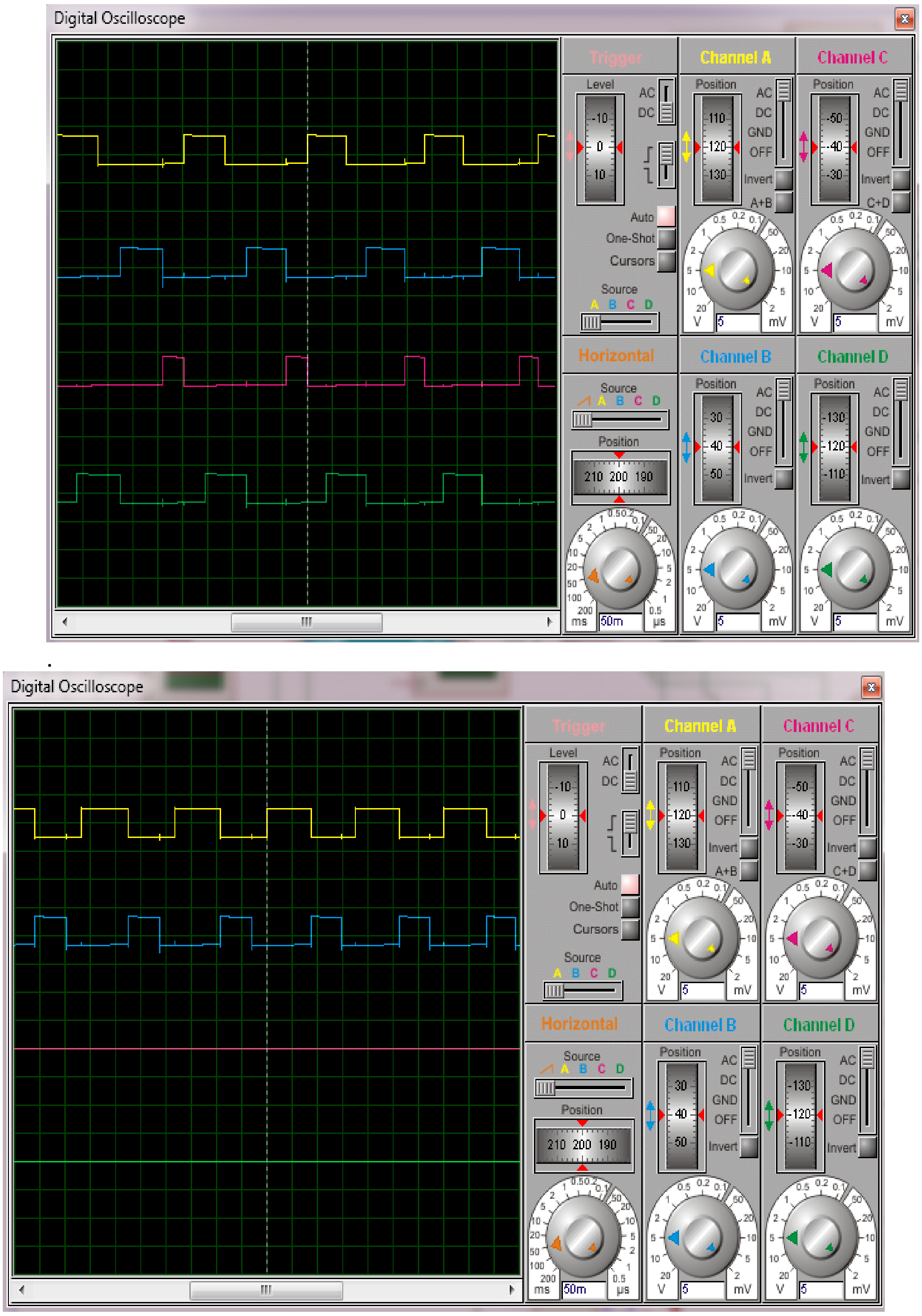

Fig. 9=7. Counter-Clockwise (CCW) Switching MOSFET

3. Conclusion

Previously, the design and simulation of the tool making program as well as testing the speed settings for the BRUSHLESS DC motor have been carried out. So in this case it can be concluded that by increasing the value of the duty cycle it will increase the speed of the motor and increase the output voltage of the inverter and increase the current of the inverter and with the increase in the switching frequency given it will increase the speed of the BRUSHLESS DC motor. After testing and discussing this tool, the authors suggest that in addition to using a hall sensor as a rotor position detector, it may also be possible to use a back-emf motor circuit because by using a hall sensor when the motor speed is too high, the hall sensor is often not read.

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