BRUSHLESS MOTOR CONTROLLER FOR NANOTEC DB22L01

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Abstract: *This project is aimed at achieving a laboratory layout in order to highlight a method to control the Brushless DC electric motor NANOTEC DB22L01. This project was modularly built, each block having a distinct destination. I.E. the first block is the control unit which includes the microcontroller, the on/off button and the programming interface for the microcontroller (ICSP a serial converter). The second block includes the power block (the driver for MOSFET transistors and an inverted H montage). The driver for TC4469 transistors is necessary to adjust the current level between the field effect transistors and the microcontroller outputs, while the inverted H bridge generates the signal that controls the motor (ΦA, ΦB and ΦC) from the six complementary signals generated by the microcontroller (AL, AH, BL, BH, CL, CH). The whole assembly was fixed on a Plexiglass plate in order to give a pleasant appearance to the project. A LCD display is located on top of it showing the engine rotation speed and the current consumption. We can change the rotation speed of the motor using the on-mounted potentiometer.*

Keywords: *electric motor, transistor driver, inverted H Bridge, microcontroller, potentiometer*

1. INTRODUCTION – ELECTRIC MOTORS

An electric motor is an electromechanical device that converts electrical energy into mechanical energy. Regardless the type of motor, it is built into two parts: the stator and the rotor. Generally the stator is fixed externally to the motor and includes the housing, the power terminals, the stator ferromagnetic armature and the stator winding. As the moving part of the motor, the rotor is placed usually inside. It consists of a shaft and an armature that supports the rotor winding. An air gap exists between the stator and the rotor allowing the movement of the rotor toward the stator. The thickness of the air gap is an important indicator for the motor performance. Most of electric motors run based on the exploitation of the electromagnetic field that acts on a conductor carrying electrical current. Built within a various range of electrical powers, electric motors are used in different domains such as electronic components (HDD, CD-ROM, printers), and large electrical power drive systems (pumps, locomotives, cranes) as well.

According to the type of current that goes through, electric motors can be classified into AC motors and DC motors.

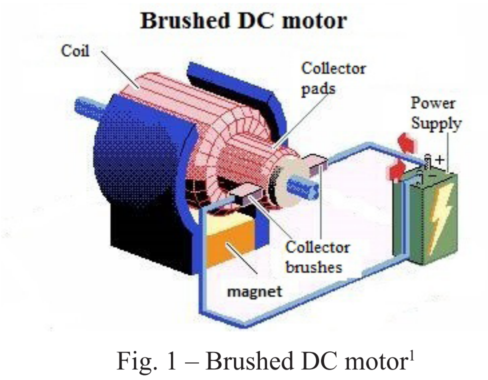


Fig. 1 – Brushed DC motor[1]

As well, depending on the number of electrical current phases, the electric motors can be classified as single phase motors or multiphase motors.

[1] www.robotics.ucv.ro

The DC motors runs based on a current that does not change direction, i.e. the continuous current. The magnetic poles and the concentrated magnetic coils generating the magnetic field excitation are placed on the motor stator. On the motor shaft a manifold is located which changes the direction of flow through the rotor winding so that the magnetic field excitation continuously exerts a force to the rotor.

Types of motors:

- DC motors with or without brushes;
- Stepper motors;
- AC inductive motors;
- Switched reluctance motors.

The first two types are used more often in microcontroller applications. A motor can be controlled by a microcontroller both directly and through specialized programmable interfaces.

2. BRUSHLESS ELECTRIC MOTOR

Brushless DC motors (BLDC) are preferred for the higher efficiency of low power motors, quiet operation, compact size, and reliability as well as the cheaper and easier maintenance. This type of motors can perform the most complex revolution in the domestic appliances field including washing machines, air conditioners, refrigerators, vacuum cleaners. By this time, domestic appliances were run mainly on motors made by traditional technologies, such as single phase AC and universal motors.

These classic engines typically operate at a constant speed directly from AC power source not taking into account efficiency increase. Consumers today want to acquire low power consumption, high performance, and low noise products. Traditional technologies cannot provide these solutions.

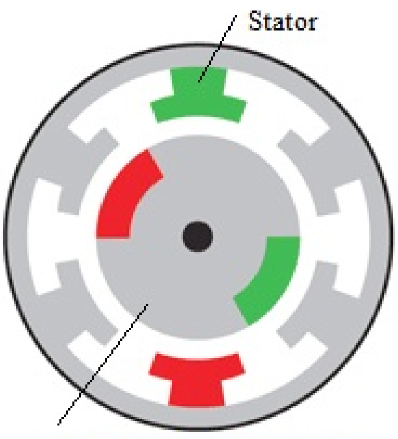


Fig. 2 – BLDC Structure[2]

2.1 BLDC structure A Brushless DC motor is mainly designed as a permanent magnet rotating into a winding through which electrical current flows. To this respect it equals an inverted DC motor, wherein the magnet rotates while the conductors remain still. In both cases, the current flowing through the conductors must reverse polarity every time a magnetic pole passes by the conductors to ensure the single-direction action of the couple. With the classic collector-equipped DC motors, the polarity reversal is performed by the collector-brush assembly. As the collector is mounted on the rotor, the commutation moments automatically synchronize with the alternant polarity of the magnetic field which is crossed by the conductors. Reversal of current polarity in the brushless DC motor is performed by power transistors which are to be switched in synchronism with the rotor position.

2 http://www.freescale.com/webapp/sps/site/overview.js

2.2 BLDC VS. Conventional DC motor With a conventional DC motor, the collector brushes mechanically touch a set of electrical contacts on the rotor (called the switch-collector), establishing an electrical circuit between the DC power supply and reinforcement wound armatures. While the plates rotate, the stationary brushes come into contact with different sections of the collector. The system consisting of the collector and brushes includes a set of electrical switches, each of them operating in frequency so that the electric power is always distributed through armatures near the stator – permanent magnet.

In a BLDC motor the electromagnets remain still while the permanent magnets rotate and the armature is not moving. This solves the issue related to power transfer to a moving armature. In order to do it, the switch assembly is replaced by an electronic controller. The controller performs the same power distribution as in a conventional DC motor, just using a "solid state" fixed circuit instead of a collector. The multiple benefits of BLDC motors compared to the conventional DC motors are as follows:

- Fast dynamic response;
- Increased efficiency;
- Longer lifetime;
- Noiseless operation;
- Higher rotational speeds.

Nevertheless, cost is the main disadvantage of BLDC motors, as they require complex speed controllers to operate.

3. THE MOTOR USED FOR THE PROJECT

The motor used for this project is DB22L01 made by Nanotec. This is a brushless DC motor equipped with inside-mounted rotor fixed to the shaft.

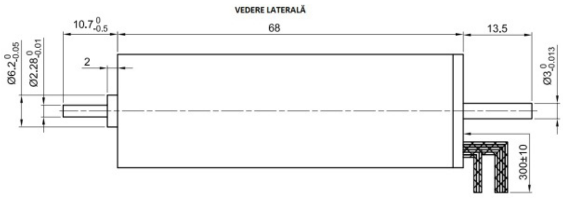
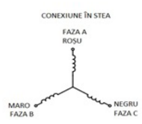


Fig. 3 –Nanotec DB22L01 Side-View

Table 1 – Nanotec DB22L01 Connectors

CONNECTOR TABLE					
	PIN	COLOR	FUNCTION	DESCIPTION	FUSE
8 pole motor	6	Red	U		UL 1007 AWG 28
	7	Brown	V		
	8	Black	W		
Hall sensor pinout	1	Blue	Vcc	Hall sensors power supply	UL 1007 AWG 26
	2	Red	HALL A		
	3	Yellow	HAL B		
	4	Brown	HAL C		
	5	Green	GND	Hall sensors ground	
Encoder (optional)	6	Yellow	A		
	7	Brown	A\		
	8	Gray	B		
	9	Gray/Pink	B\		
	10	Violet	I		
	11	Red/Blue	I\		

This motor contains 8 poles and 3 phases that are necessary to perform control.

The specifications include 24Vdc power supply; it can reach maximum currents of 1.5A; and the maximum power is 20W. This type of motor has a maximum number of 3500 rev/min. three Hall sensors are used in open collector montage in order to establish any time-rotor position against the stator windings, and reduce energy consumption. Therefore they are 5Vdc supplied for operation through a pull-up resistor.

4. CIRCUIT OPERATION

In order to outline the assembly, we designed the whole circuit electrical diagram.

It displays the two essential components of the model: the microcontroller part – the brain of the circuit, and the second one - the power driver (MOSFET transistor driver and inverter H Bridge).

Nanotec DB22L01 is the Brushless DC electric motor required to embody this project; it is a three-phase motor which includes Hall sensors to establish rotor position against the stator.

The closed-loop diagram stands for the control scheme of the motor. This means that additionally to the control circuit starting from the microcontroller to the motor, there is a feedback circuit which conveys information from the Hall sensors to the microcontroller, to enable the decision making process and establish the control phase.

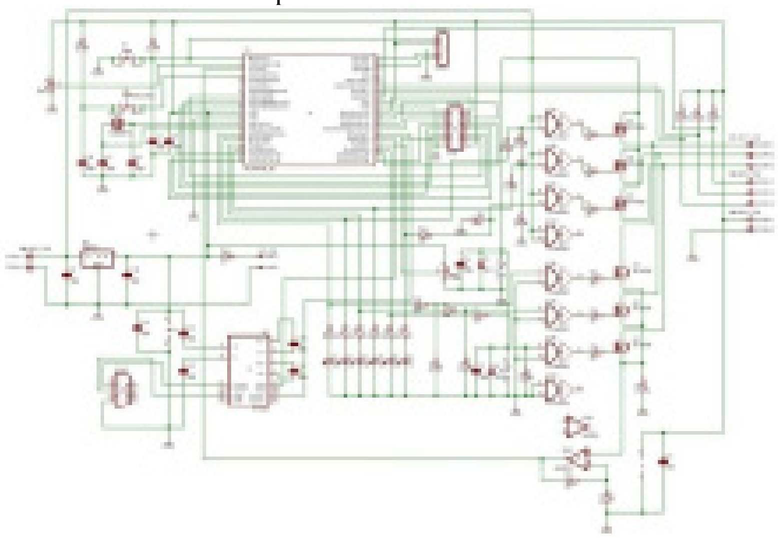


Fig. 4 – The Complete Wire Diagram

As the motor is three-phased, its control sequence is divided into six (Fig. 5), and the signal from Hall sensors is divided into two for each sensor – for instance A sensor state is High (logical 1) for a rotation of 180°, while the other 180° is set to Low (logical 0).

The following figure illustrates the temporal correlation between the signal generated by sensors and the control signal for each phase and stage in part.

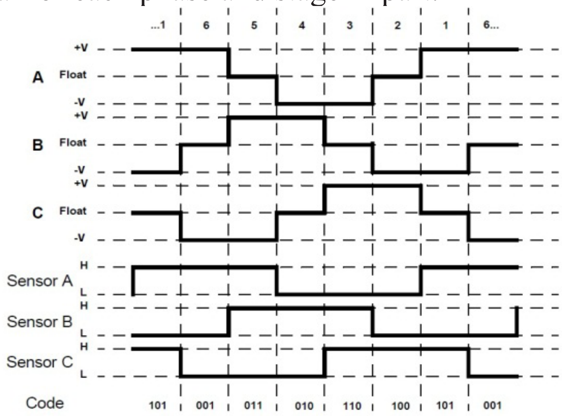


Fig. 5 – Conduction Time of the Transistors

This figure displays two adjacent sensors conducting through a 60° length at the same time.

The same chart illustrates the leading windings at a moment in time, and even the direction of the current flow through the coil. For example related to the 6th phase, the leading winding the electric current passes through from A to C is the A-C winding and A is the leading the sensor. Two ways to connect to the microcontroller can be seen on the same circuitry, based on a programmer (ICSP connection) or via serial connection (ST232 converter). Serial connection was implemented in order to achieve real-time monitoring of microcontroller's states and responses and execute direct control from the keyboard of a computer.

The wiring diagram includes an LCD display aimed at displaying the motor speed and the current it consumes. In order to display the control signal, the easy way of using optical LEDs was chosen, even if at high speed their latency and the integrator character of the human eye makes them look like they are all on. At low speed or even when manually turning the rotor (assuming that the motor is not powered up but the low power – microcontroller and Hall sensors are connected to the power supply) the control signal on each phase can be seen, as generated when perceiving the signal from the Hall sensors. The LEDs are physically located at AH-BH-CH-AL-BL-CL from left to the right.

After all blocks are fed (the low power part at 9Vcc – as the circuit has a 5Vcc stabilizer, and the high power part at 12Vcc, maximum 24Vcc.) press the START button to ignite the motor. At this moment it is possible for the rotor to be perfectly aligned with the stator's windings and the magnetic field not to be able to initialize the revving of the motor. This can be avoided based on software methods, including into the code a sequence of initialization of the motor. In this sequence the motor starts in an open loop, regardless the Hall sensors response, then it goes back to closed loop control. A potentiometer was used to control the motor revving, which is done by measuring the voltage between a terminal pin and the cursor.

The current is measured based on the voltage level fallen on the resistor mounted in the source of the transistors on the H bridge. Both current and speed are then displayed on the LCD display mounted on the layout.

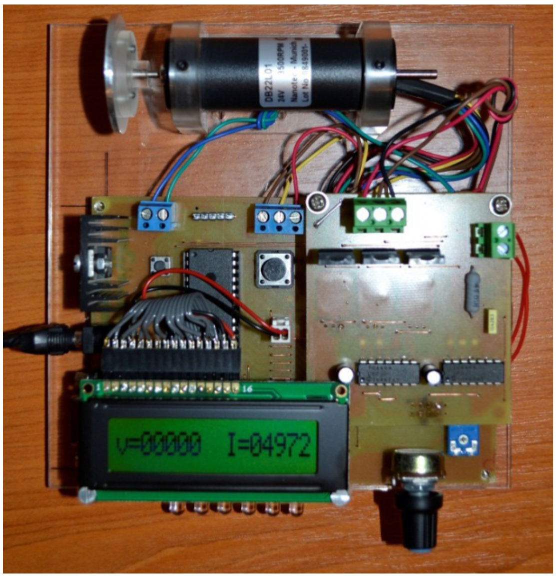


Fig. 6 – The Layout

CONCLUSIONS

In order to establish how the Nanotec DB22L01 motor works a preliminary documentation was necessary first because in the catalogue datasheet the procedure related to the internal connection of the Hall sensors was not shown. It was necessary for me to have in view other applications based on this type of motor.

Therefore I concluded that the sensors are open collector-mounted and in order to be connected to a microcontroller they need to be connected to a 5Vcc power supply through a pull-up resistor. Until the acquisition of the LCD and in order to make things easier, I decided to use a boot loader enabling control execution directly from the computer via serial connection, while the controller response could be real time watched on the computer's monitor.

PIC18F458 was my microcontroller option as it disposes of a memory-program space which is bigger than the one in the PIC16FXXX microcontroller family as well as of an increased stability to high frequencies due to the LAT registry.

If my 5Vcc stabilizer was not supplied from a commercial switch source, my microcontroller would be reset as a result of voltage variations. I replaced two potentiometers used for the establishment of Uref (revving variation) as they had genuine shortfalls, not having a linear variation of the resistor and being disrupted (lack of contact).

In order to simplify the circuitry I connected the motor and the power block to 12Vcc source as well. I installed a metal disk on the motor shaft to see whether is revving or not. The disk enables subsequent upgrades, such as installation of a slit disk and optical sensors on the chassis frame in order to establish the rotation speed. To motivate the voltage coming from the final transistors source, the signal level needed to be amplified in order to get convincing values. As the current was measured from a source with variations, I used a software filter presented like a vector which includes instantaneous values; therefore the displayed current is an average value of the 20 instantaneous values included into this vector.

For a pleasant appearance of the layout I used a backlight LCD display fitted with a program on/off switch.

To verify the control signals I used a 4-channel capture plate from Agilent – PCI 1711.

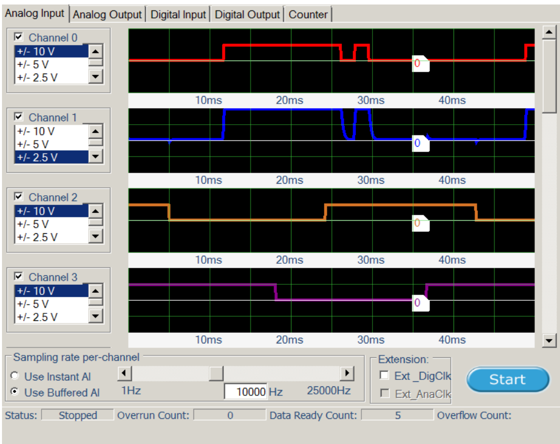


Fig. 7 – Control Signals

At this moment, the motor starts in closed loop control, therefore when pressing the START button there is a chance for it not to start spinning. This is the result of the rotor being aligned with the stator windings. This issue could be solved by introducing a sequence of initialization that entails the motor to start in open loop control, and then by generating a control signal within the closed loop control.

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