Design of Simple Controller for Minicar BLDC Motor Based on Low Cost Microprocessor

Yu Tao*, Doo-Young Song*, Zhang Lei*, Sung-Jun Park*, Tae-Uk Jung**, Cheul-U Kim***

Chonnam National University*, Korea Institute Technology Gwangju Research Center**, Pusan National University***

Abstract

If used to drive the minicar, the BLDC Motor has advantages of weightless, efficient, small-size and credibleness. In this paper at first the position detecting method for BLDC was introduced, secondly the simulation of control algorithm was done and at last the prototype controller based one chip processor MEGA48 was fabricated. The controller proposed has characteristic of cheap cost, reliable performance and totally meeting demands of minicar control.
Keywords: *Minicar BLDC, low cost microprocessor, MEGA48, multi-case sensorless signal generating method*

1. Introduction

BLDCM has the good performance on speed control as DC motor and advantages of simple construct, reliable operation and convenient maintenance as AC motor. When it applied in minicar BLDCM control system, the cheap and good performance control system design is demanded. Though by use of some motor-control chip or DSP processor we can design some excellent control system, these methods are often with complex structure and high cost that it not suitable for the minicar control system. In this paper a simple controller for minicar BLDC motor based on low cost microprocessor MEGA48 is designed and a novel multi-case sensorless signal generating method is proposed. Through the simulations and prototype controller it is clarified that the proposed control method and novel sensorless signal generating method is satisfied the demand of minicar BLDCM control system.

2. Theory of BLDCM Control

2.1 Driver circuit

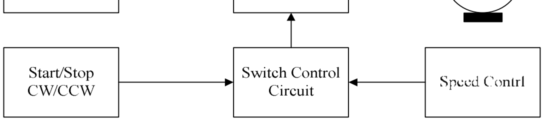


Fig. 1 Structure of BLDCM driver

The common driver circuit is connected with BLDCM as shown in figure 1. There are DC power part, Full-Bridge inverter part, Start/Stop control part, Speed control part and Switch control circuit part. Brushless DC motors are used in a growing number of motor applications as they have many advantages. They have no brushes so they required little or no maintenance. They generate less acoustic and electrical noise than universal brushed DC motors. They can be use in hazardous operation environment.

They have a good weight/size to power ratio. Such types of motor have a little rotor inertia; the coils are attached to the stator. The commutation is controlled by electronics. Commutation times are provided either by position sensors or by coils Back Electromotive Force measuring.

2. 2 Operation theory

In the BLDC control system for estimating the rotor position, three hall sensors are positioned. With these sensors, 6 different commutations are possible. Phase commutation depends on hall sensor values.

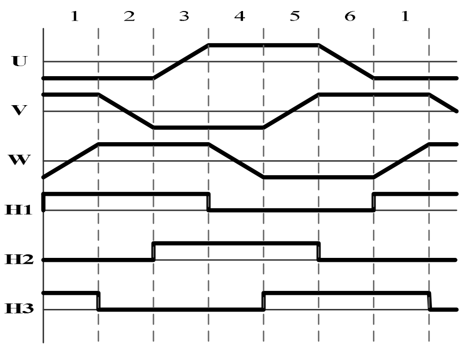


Fig. 2 Back-EMF and Hall-sensor signals

The generally accepted definition of a BLDC motor is a permanent magnet motor with trapezoidal back-EMF, as opposed to the sinusoidal back-EMF found in permanentmagnet synchronous motor. The typical trapezoidal back-EMF waveforms and corresponding driving voltages of a 3-phase BLDC are shown in Figure 2. In every commutation step, one phase winding is connected to positive supply voltage, one phase winding is connected to negative supply voltage and one phase is floating. The zero crossing occurs right in the middle of two commutations. At constant speed, or slowly varying speed, the time period from one commutation to zero-crossing and the time period from zero-crossing to the next commutation are equal. This is used as basis for this implementation of sensorless commutation control.

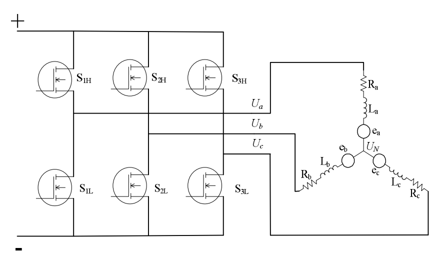


Fig. 3 BLDCM driver structure

$$U_a = R_a I_a + L_a \frac{dI_a}{dt} + e_a + U_N \quad (1)$$

$$U_b = R_b I_b + L_b \frac{dI_b}{dt} + e_b + U_N \quad (2)$$

$$U_c = R_c I_c + L_c \frac{dI_c}{dt} + e_c + U_N \quad (3)$$

$$U_a + U_b + U_c = e_a + e_b + e_c + 3U_N = 3U_N \quad (4)$$

$$U_N = \frac{U_a + U_b + U_c}{3} \quad (5)$$

When the polarity of one phase is commutating, it can be known from the figure that U_N is zero. And the voltage of floating phase is

$$U_{floating} = e_{floating} + U_N \quad (6)$$

$$e_{floating} = U_{floating} - U_N = U_{floating} - \frac{U_a + U_b + U_c}{3} \quad (7)$$

For example if phase C is floating, then

$$e_{floating} = U_c - \frac{U_a + U_b + U_c}{3} = \frac{2U_c - (U_a + U_b)}{3} \quad (8)$$

Before the commutating point when the voltage of floating phase is from positive to negative, $e_{floating}$ is positive; by contraries when the voltage of floating phase is from negative to positive, $e_{floating}$ is negative. The voltage U_a, U_b and U_c can be detected by voltage sensor circuit. By use of comparator the 'zero crossing' point of back-EMF can be generated. It is obvious that the phase change point delays 30° than the 'zero crossing' point. We can find the phase change point from the 'zero crossing' point not only through hardware method but also through software method. In this paper the filter capacitor is used to generate the phase change point signal. On high RPM the phase change point signals are almost same as the hall sensor signals. On low RPM, thought there is a little phase delay between the phase change point signals and the hall sensor signals, it can be amended through software method.

3. Control Algorithm

3.1 System Command

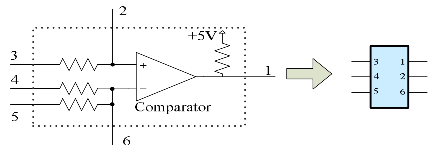
The system controls include speed control, start control, stop control and CW/CCW control. The upper switch unipolar PWM technique is used to control the output voltage of Full-Bridge inverter and then control the speed. The operation speed is detected by software in real-time and fed back to CPU. Start and stop are controlled by the external inputs. The exception handles can reset the controller when exception happens.

3.2 MEGA48 Features

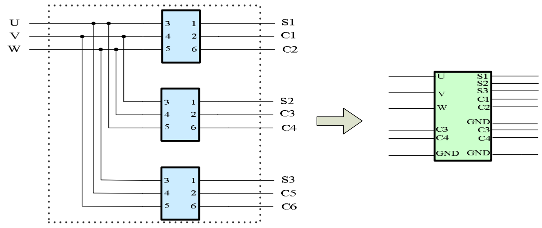
The ATmega48 is a low-power CMOS 8-bit microcontroller. The ATmega48 provides the following features: 23 general purpose I/O lines, three flexible Timer/Counters with compare modes, internal and external interrupts, a programmable Watchdog Timer with internal Oscillator and Six PWM Channels. It has cheap price that suitable for the low cost control system.

3.3 Multi-case sensorless signal generating method

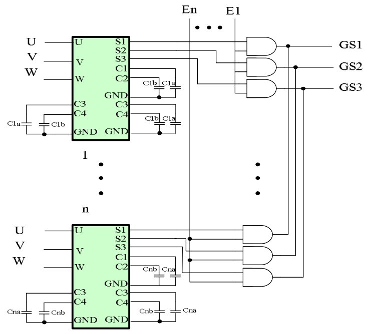
When senesorless signals are generated from back-EMF, the zero crossing point leads 30° than the phase change point. There are many methods can solve this problem. The representative ones are software method and hardware high-pass filter. If solved in the software the program will turn to complex and calculate time of MCU will be cost. Here the multi-case sensorless signal generating method is proposed as shown in figure 4.



(a) Comparator Unit



(b) One case of Signal generating circuit



(c) Multi-case system of sensorless signals generation

Fig. 4 Multi-case commutating signal generating method

As we known the high pass filter can be set to appropriate some definite frequencies by using proper capacitor and resistance. But the operation band in each combination of one case is limited. If the multi-case technique is applied here the problem is resolved. The Microprocessor can select the proper commutating signals by the speed at that time through the AND gate.

3.4 Software Flow

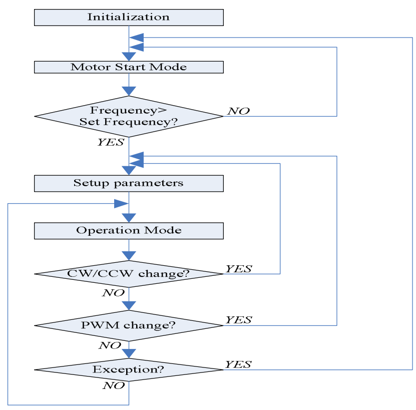


Fig. 5 Flow block of control system

The control order of program in MEGA48 is shown as figure 5. Through this control method the command of system can greatly satisfied.

4. Simulations and Results

4.1 Simulation in Psim

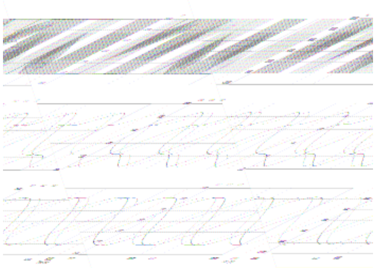


Fig. 5 Simulations of the phase voltage and calculated voltage

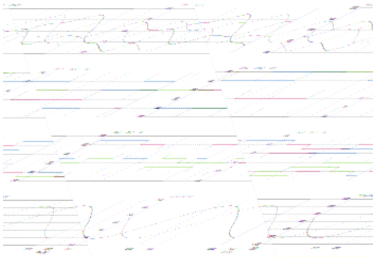


Fig. 6 Simulations of signals generation when the filter is set to 60 Hz

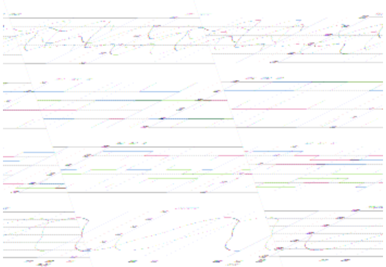


Fig. 7 Simulations of signals generation when the filter is set to 120 Hz

Figure 5,6 and 7 are the simulation results in Psim. It can be known that the signals can be made similar as the hall-sensor signals in despite of filter frequency from the figures above.

4.2 Result Waves

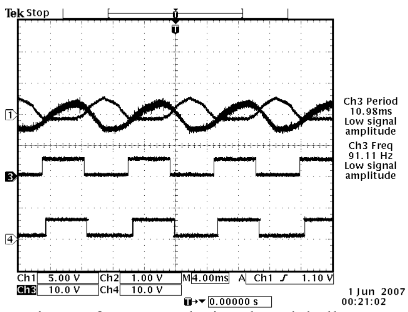


Fig. 8 Comparison of generated signal and hall-sensor signal when RPM is high and PWM duty is set go 100%(255)

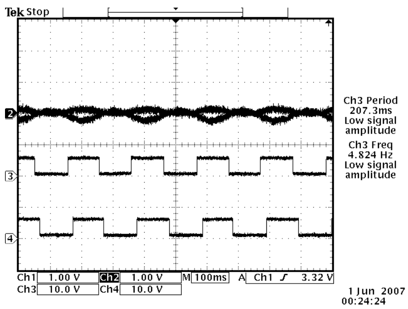


Fig. 9 Comparison of generated signal and hall-sensor signal when RPM is low and PWM duty is set go 100%(255)

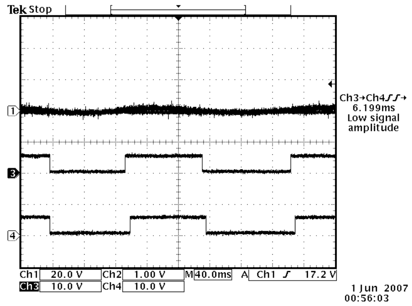


Fig. 10 Comparison of generated signal and hall-sensor signal when RPM is low and PWM duty is set to 13.7%(35)

Figure 8,9 and 10 show the generated signals and hall-sensor signals in different RPM and PWM parameters. It is obvious that the sensorless commutating signals generated by the method proposed are very similar to the hall-sensor signals in despite of high or low RPM when motor is operating.

4.3 Prototype Control system

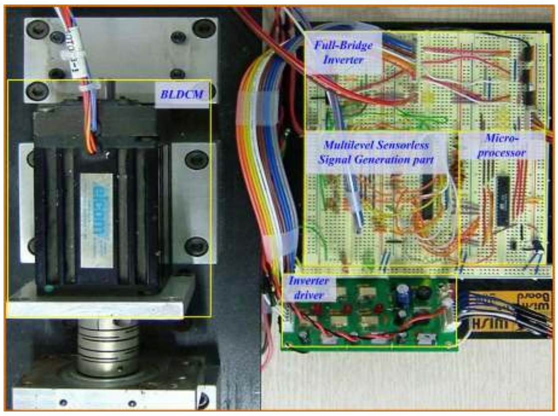


Fig. 11 Photo of prototype control system

Figure 11 is the photo of prototype system made for test. It consists of BLDC motor, inverter drive circuit, full-bridge inverter, multi-case sensorless signal part and microprocessor part.

5. Conclusion

For satisfying the command of minicar BLDCM control system we designed the cheap and high performance control system. The multi-case sensorless commutating signal generating method is proposed. Through simulations and real test in lab, we found that the control algorithm is suitble for the command of the mini car system. The system is simple and the performance is stable. By using the low cost microprocessor MEGA48 and general semiconductor chips the cost of system is reduced.

Reference

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