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A Study on the Enhanced Filtering for the Removal of BEMF in BLDC Motors

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Abstract

This paper used the majority function to digitally filter back-electromotive force as an explanation of the Brushless DC MOTOR control algorithm. The cause and improvement of motor noise, which are operating in close proximity to high frequency sources, did not use conventional low pass filter and comparator elements. Also, they repeatedly output a noise-free BEMF signal for the input value of the majority detection filtering. These filtering steps can help reduce costs and minimize the area of a PCB by requiring relatively little hardware.

Key words : BLDC, BEMF, DC motors, PWM, PCB, LPF

Ⅰ. Introduction

There are also a number of components that are essential to the development of ICT convergence products and are being developed to miniaturize and integrate like products. Among them, a motor is an essential part of product design because it can turn electricity into kinetic energy. Despite these advantages, however, motors generate a lot of noise due to their nature. Noise generated from the motor may be emitted by cables from inside the product or dumped into the PCB, causing malfunction of the circuit. Motors can be broadly classified according to whether they are direct current or alternating current, and are subdivided into different types of motors. Among them are DC motors, BLDC motors and Step motors, which are commonly used in product design [1], [2], [3].

Among them, the BLDC motor is a motor without a brush. Because there is no brush, it is less noisy and can be used semi-permanently. On the other hand, switching circuits can be cumbersome, since the switch must be used to change and input poles according to the position of the rotor. Also, even if the noise generated by the brush disappears, another noise is generated by switching circuitry, one of the main sources of noise [4], [5].

Noise characteristics can be largely divided into CM and DM or NM components. CM noise refers to noise that has the same phase among the noise components that flow through a circuit. In the case of motors, noise in the same phase is dumped on the power line or signal line when the motor is referred to as the source of noise. As opposed to CM noise, DM noise in a circuit is opposite to each other. In other words, it is noise that flows in the form of a loop in a circuit. Excluding the design of instruments, the

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noise measures presented in this paper have been studied on how to reduce noise emitted from motors to the maximum extent possible [6], [7].

II. Experiments

As the BLDC motor rotates, each winding produces a BEMF which has the opposite polarity to the main voltage applied, according to the law of the lens. The polarity of the BEMF is the opposite of the direction of the applied voltage and is determined by the number of turns of the stator winding, the angular speed of the rotor, the magnetism produced by the rotor magnet, and the above three motor parameters. Figure 1 shows the BEMF signals generated during operation of the BLDC motor.

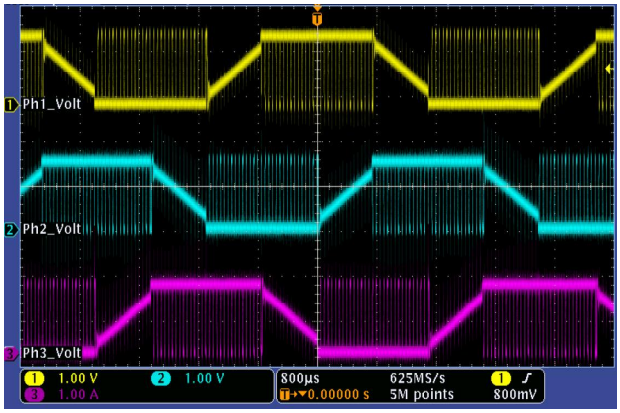

Figure 1. BEMF on all 3 phases.

When the speed changes, and the characteristics of the motor winding change from time to time, the BEMF is also changed, and the digital filter is performed to software remove the switching noise component of high frequency from the retro-power signal [8].

We used a non-linear digital filter called the “Majority Function” above the BEMF sensing function. The Majority function filter uses two logical operators. The AND operator was used to detect BEMF signals, and the XOR operator was used to detect rising and falling edges at the BEMF signals. The sampling point of the BEMF signal is variable for the PWM ON time zone determined by the speed of the motor. At low speeds, the BEMF signal is sampled at 50% of the PWM ON time zone and the sampling point is increased as the subsequent speed increases. At 100% duty cycle, samples are made at 80% of PWM ON time, which is the maximum point.

Figure 2 and Figure 3 sample points are shown. Sampling the BEMF signal at 20 kHz may reduce switching noise at the sampled BEMF signal. Therefore, a filter using the Majority function is used. The Majority function is a function that has n binary inputs and outputs the most frequently entered values.

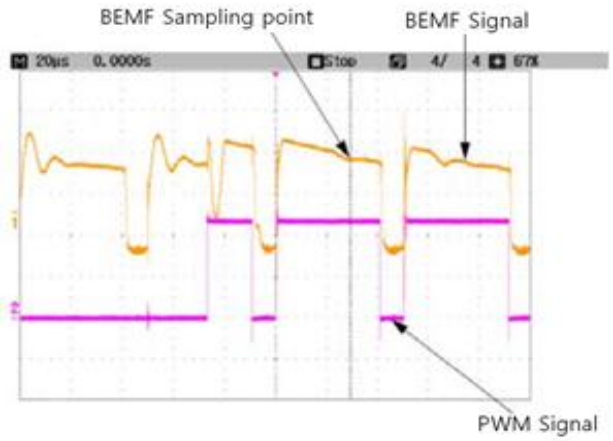

Figure 2. BEMF sampling point with 80% duty cycle.

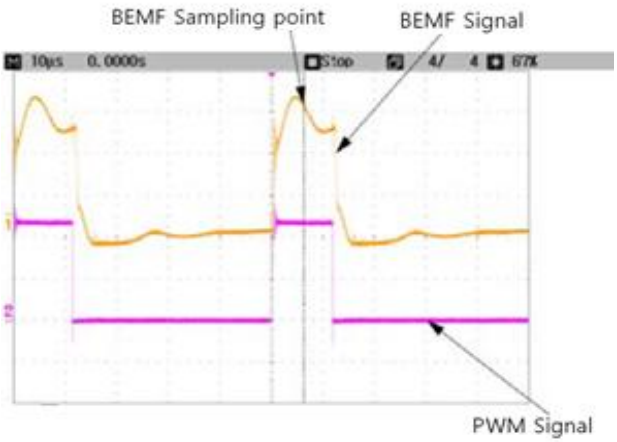

Figure 3. BEMF sampling point at 20% duty cycle.

If there are three inputs, as shown in Table 1, the output value will output values that have

occurred at least two times. The Majority value can be expressed as in Equation 1, using the logical operator AND(^). In addition, OR(v) can be used to express as in Equation 1. The function used in Equation (1) is a function from n inputs to one output. The value of the operation is false when n/2 or more arguments are false, and true otherwise. Also, representing true values as 1 and false values as 0, we may use the formula.

Table 1. majority functions with three inputs.

A	B	C	Majority
1	1	1	1
1	1	0	1
1	0	1	1
1	0	0	0
0	1	1	1
0	1	0	0
0	0	1	0
0	0	0	0

$$Majority = (A \wedge B) \vee (A \wedge C) \vee (B \wedge C) \quad (1)$$

If Boolean Presentation of the Majority Function is reflected, the two identical values will reflect 66% of the input. Therefore, performing a non-linear filter using the Majority function is based on six samples. Samples can be shown as shown in Table 2 on digitized BEMF signals. In Table 2, 51% of the three upper samples are “1” and 51% of the three sub samples are “0”.

Table 2. Results of performing non-linear filters of the majority function.

A	B	C	Majority
1	1	1	1
1	1	0	1
1	0	1	1
1	0	0	0
0	1	1	1
0	1	0	0
0	0	1	0
0	0	0	0

The BEMF signals are filtered using a Majority detection filter, which is performed with special logical test conditions to change the DATA. The output of the logical test condition is represented as true and false, and this output value is used as input to the Majority detection filter. The filter made three consecutive false state checks to detect noise. Repeated filtering will output a binary representation of a noise-free BEMF signal. It is a way to minimize BEMF using digital filtering proposed in this paper.

III. Conclusion

This paper used a nonlinear digital filtering algorithm to improve BEMF, without using hardware low pass filter, comparator parts. Majority Detection Function was used to detect BEMF signals generated by rotation of BLDC motors. Digital filtering can detect noise accurately in BEMF signals. The key to sensorless control of BLDC motors is to detect noise accurately in BMEF signals. As opposed to using hardware filters or external comparators, digital filtering requires relatively little hardware, which can reduce electronics costs and minimize the area of PCBs.

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