A LOW COST SPEED CONTROL SYSTEM OF BRUSHLESS DC MOTOR USING FUZZY LOGIC

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Abstract
In this paper, focuses on a low cost speed control system using a fuzzy logic controller for a Brushless DC Motor. In a digital controller of brushless DC Motor, the control accuracy is of a high level, and it has a fast response time. We used a hall IC signal for the permanent magnet rotor position and for the speed feedback signals, and also for a micro controller of 8-bit type (80CL580); furthermore, we designed the fuzzy logic controller and implemented the speed control system of brushless DC Motor. To acquire an accurate fuzzy logic control algorithm, a simulation with the MATLAB program has been made, while the performance of the system, done with an experiment for a unit step response, was also verified.

Introduction

Recently, a brushless DC Motor (BLDC) has been rapidly demanded due to preciseness of industrial technology and increase of various kind of control device. Because a brushless DC Motor is suitable as a servo motor because of its high efficiency and excellent control character. So, we designed a low cost controller for brushless DC Motor, with high rely on quality. In this paper, fuzzy reasoning algorithm was adapted to response well to various kinds of load. Also, the 80CL580 that is 8 bit CPU was used to produce the system for a low cost. Additionally we designed a F/V converter to monitor a digital speed change in analog signal for a efficiency analyzing. So we evaluate a step response characteristic and experimented response characteristic in a instant torque change using torque meter device.

Proposed System

Figure 1 shows a block diagram of proposed system.

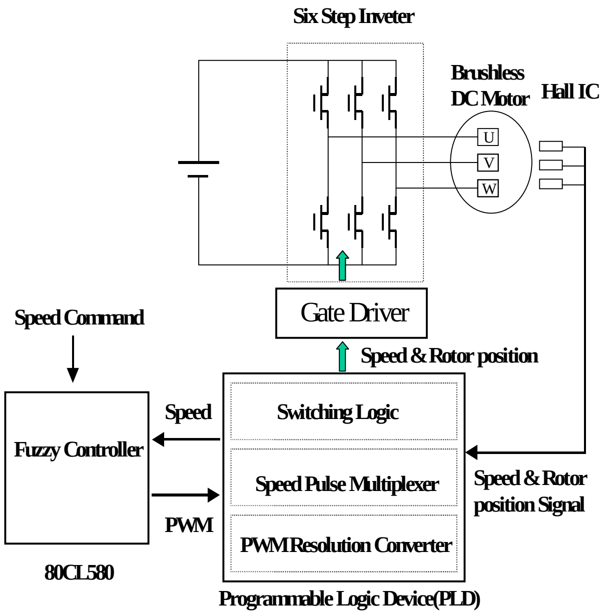

Figure 1. Overall System Block Diagram

The system above is composed of brushless DC Motor, six step inverter, gate drive of inverter, PLD (Programmable Logic Device), and fuzzy reasoning controller. Switching logic, speed multiplexer, and PWM resolution converter are located within the PLD. Switching logic, speed multiplexer, and PWM resolution converter are located within the PLD. Initially, the hall IC signal feedback occurred starting the motor by speed command. Logic signals of FET are generated using these three hall IC signals in the switching logic part. This circuit is shown in figure 2.

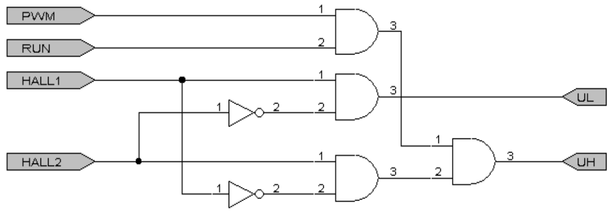

Figure 2. The signal of one phase.

Only one phase of driving part is shown in this figure, it is realized using FET gate switching signals that are generated mixing hall IC signals and using AND operation between PWM which is speed control signal and RUN signal which is control of RUN/STOP. Also, only one speed signal is created using three hall IC signals in the speed pulse multiplexer. This circuit is shown in Figure 3.

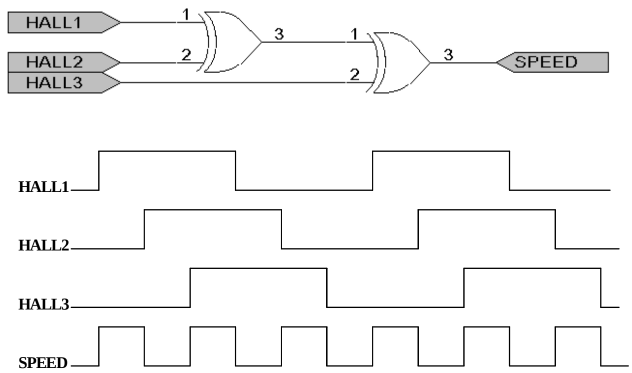

Figure 3. The speed pulse multiplexer.

In figure 3, we extend frequency as three times using XOR logical operation because the resolution of frequency is low related to speed at one hall IC signal. The PWM duty ratio for motor control is generated using the fuzzy reasoning algorithm, and the speed command that was input by speed signal feedback with fuzzy controller. The circuit for a PWM resolution is shown in Figure 4. The resolution range of a PWM Duty Ratio supplied in an 80CL580 micro controller is 0 ~ 255. As the circuit of Figure4, we enhanced the PWM Duty resolution to 2 times and improved an accuracy of the speed control.

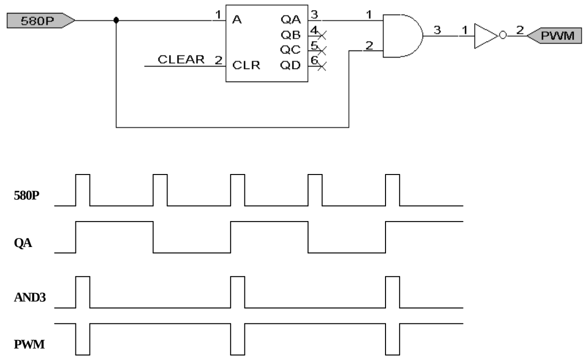

Figure 4. The PWM Resolution Converter

A specification of the Brushless DC Motor we used in this paper, are 4 pole, 6 slot, 3 phase, and a level of 50W. A speed of the motor is 2000RPM to the DC 30 V, a inductance between the phases is 25mH and resistance between phases is 3.2Ω. Therefore, to observe the switching time for a drive, the speed frequency of the Brushless DC Motor revolved at N RPM is following.

Fm = Nrpm / 60

So, the speed frequency is 6×Fm, and a switching frequency of the one FET is 2×Fm because a FET turns on/off at one time for one a period of the Hall IC signals.

Fuzzy Inference System

Recently the PI and the PID controller have been widely used as a control method of servo driving in industrial control fields. A driving specific property can be estimated well, once a control constant is properly set. But the control constant should be changed in order to maintain an optimum driving state if the driving point or the motor parameters are changed. Recently the fuzzy controller, has appeared which is based on knowledge or an experience of expert rather than on a complicate mathematical modeling. The fuzzy controller works well using experimental information even if not having mathematical modeling. Moreover, the fuzzy controller is capable of real time control using fuzzy rule base. In this study, we tried to control the speed of brushless DC Motor using Mamdani-style fuzzy inference system, which is composed of each one of input, and of output variable. Generally it is most important to assign the range of input and output membership function in the fuzzy inference engine. We defined input and output variables of fuzzy inference system in this paper as following.

$$\Delta\varepsilon = Cm - V \quad (1)$$

The fuzzy input value Δε is deviation between motor speed command Cm and hall IC sign[illegible]e V. When V_{rot} is counter step number per one ro[illegible] V becomes average motor speed of one rotation. [illegible]uzzy output ΔD changes the pulse duty D_{new} which determines motor speed so that stable speed and torque may be maintained in case of starting or load changing of motor The fuzzy rule base to control the speed of brushless DC Motor is composed of following 5 rules.

$$D_{new} = D_{old} + \Delta D \quad (2)$$

Rule 1 IF (ε is GN) then (ΔD is GN)
Rule 2 IF (ε is SN) then (ΔD is SN)
Rule 3 IF (ε is ZE) then (ΔD is ZE)
Rule 4 IF (ε is SP) then (ΔD is SP)
Rule 5 IF (ε is GP) then (ΔD is GP)

Each linguistic variable presents degree of fuzzy input and output variables. GN means great negative, SN, small negative, ZE, zero, SP, small positive and GP, great positive. On starting a brushless DC Motor simulation using fuzzy inference system, the specific response character of 1400RPM speed was controlled with initial condition of Cm as 7600 and D_{old} as 1% and was experimented in a motor load condition. Also, we implemented software simulation using the Matlab Ver 5.1 (Math Work Co.) for exact performance result of fuzzy logic reasoning and realized fuzzy algorithm in the brushless DC Motor target board.

$$= \frac{\sum V_{rot}}{6}$$

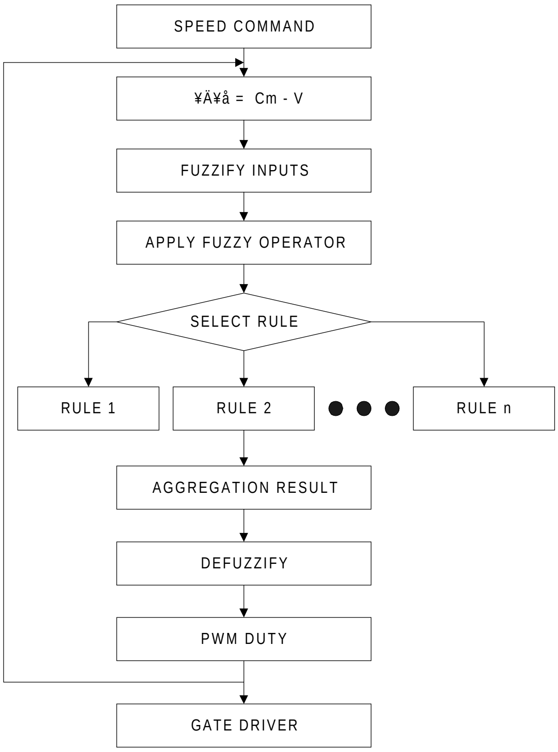

Figure 5. Flow chart of fuzzy reasoning

Figure 5. Shows the flow chart of fuzzy reasoning system. At first, to input Δε value acquired from hall IC signals to the fuzzy inference system and to fuzzify the inputs value Δε is fuzzified. Output values of fuzzy membership function to be reasoned and mapping results to be aggregated according to each rule. Then to defuzzify output result, to be effected on PWM duty and finally speed to be returned of the motor. Figure 6 shows the membership function of fuzzy input and Figure 7 shows the membership function of fuzzy output. In the Figure 6, control range of input variable Δε being between –500 ~500, two trapezoidal membership function, three triangle membership function have been used. In the Figure 7, control range of output variable ΔD being between –100 ~100, two trapezoidal membership function, three triangle membership function have been used.

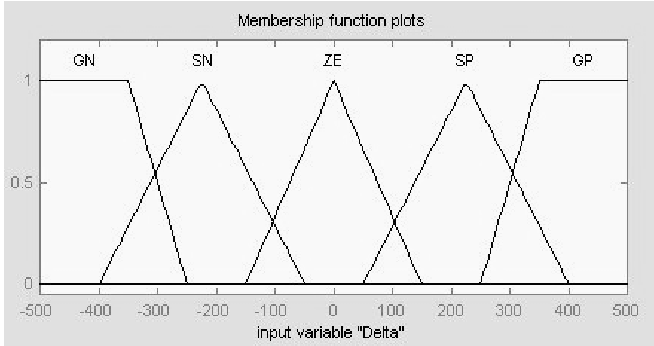

Figure 6. Input membership function

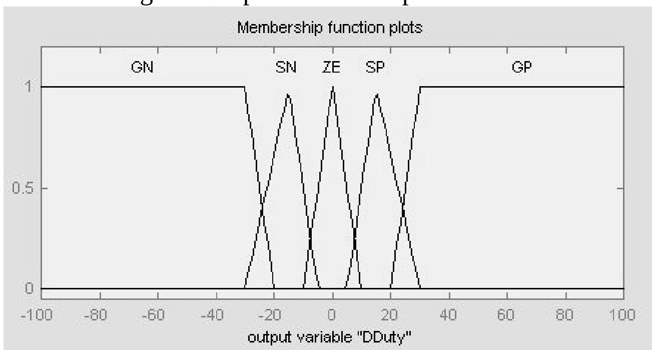

Figure 7. Output membership function

Figure 8 presents a three-dimensional curve mapping from the error value ε to the ΔD amount. X-axis is present error value Δε, y-axis is ΔD and z-axis is degree of Δε, ΔD.

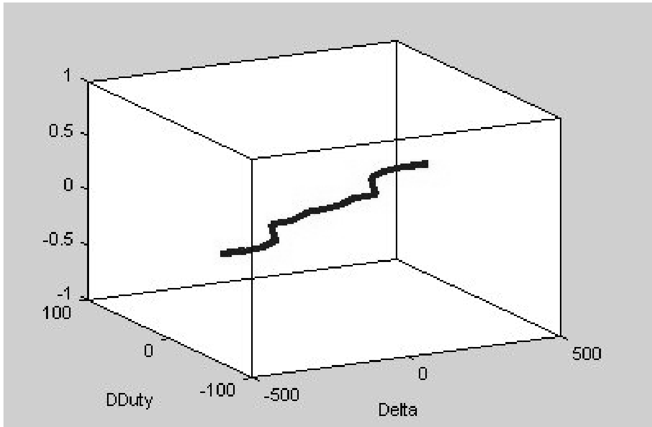

Figure 8. Three dimensional mapping curve

Experimental Result

In this paper, following the experimental set has been composed.

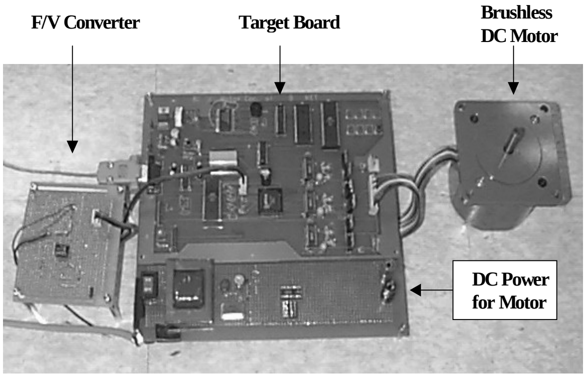

Figure 9. The Experimental Set

As the Figure 9, a controller of the motor, a driver, a RS-232C communication port, a start switch, and LED panel are composed on one board, the response characteristic of the system was confirmed using a frequency to voltage(F/V) converter. Also the Torque Meter was used to inflict a constant load. The circuit of the F/V converter module for analysis and it's frequency response are as following Figure 10, 11.

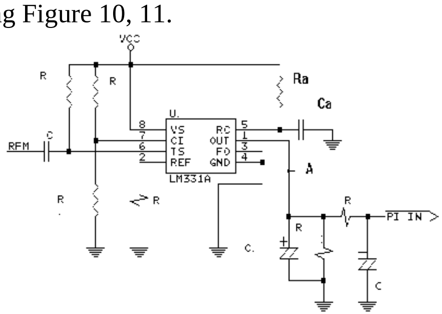

Figure 10. The Circuit of F/V Converter

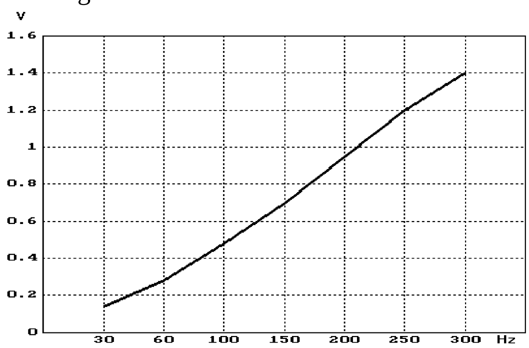

Figure 11. The Frequency Response of F/V Converter

After setting a speed command for 1400RPM in the program of the target board pushing the start switch on the board, we measured a unit step response. Also we inflicting a constant load of 500g.cm in a moment with torque meter during the operation. The characteristic of a unit step response to no load is shown in the Figure 12.

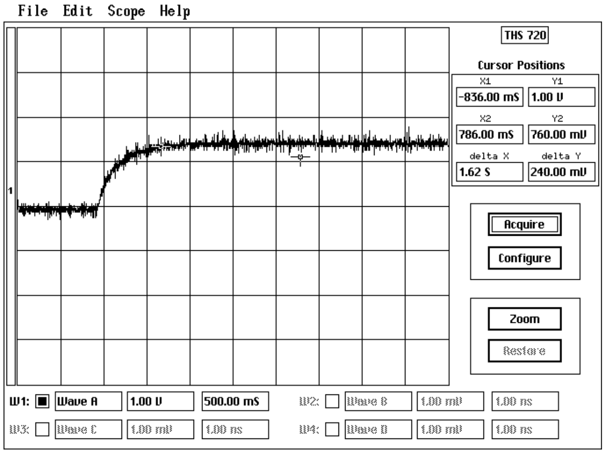

Figure 12. The Unit Step Response to no load

In this figure, the rising time to be increased up to 60% of a maximum speed is about 250ms. Also, the characteristic of a response to constant load (500g.cm) while the motor is operating of to 1400RPM is shown in the Figure 13.

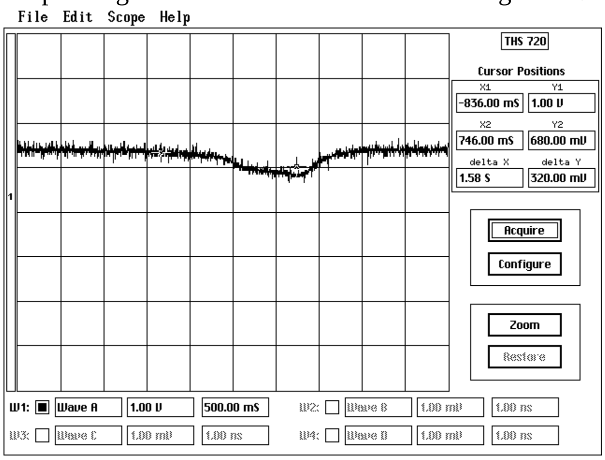

Figure 13. The Response to constant load (500g.cm)

The characteristic curve to a load variation is similar to that to no load.

Conclusion

In this paper, we realized the controller for a brushless DC Motor, which is demanded increasingly using the fuzzy logic, and evaluated a performance of the system with the experimental set. We detected a speed of the motor using only the hall IC signals instead of a expensive encoder. In this paper, we present fuzzy reasoning algorithm to control brushless DC Motor in order to improve the PI controller, which is hard to get optimum control under the unstable driving situation or different condition of load. As a low cost CPU like 80CL580 was used, execution speed was slightly slow, but we could get the same simulation result compared to the existing speed controller. Hereafter if we take advantage of PI controller and fuzzy reasoning system, better characteristic controller for speed control in brushless DC Motor may be made.

[References]

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