論文
3-2-2

Brushed Servo-Motor Control System for Industrial Robot
(산업용 로봇을 위한 직류 서보전동기 제어시스템)

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ABSTRACT

In this paper, brushed servo control system for industrial robot is realized under GUI environment. Brushed servo motor has 400W capacities, 1000ppr optic encoder and electric brake load. Especially, driving unit is composed of full-bridge MOSFET semiconductors with 9540 and 540 FET ICs. Control unit has PIC 16C74 microprocessor[1,2,3], RS-232 communication ports, URD current sensor, and GAL 16R8ACN. Servo control system is controlled by PID control method[5,8] with varying control parameters and load capacities. Brushed servo control systems which are proposed in this paper are applied to industrial robot control system.

요 약

본 논문에서는 고출력 산업용 로봇을 위한 직류 서보 전동기 제어시스템을 컴퓨터 GUI 환경[11,12]에서 제어 알고리즘을 적용하면서 실험할 수 있는 제어시스템 을 구현하였다. 직류 전동기 정격은 400용량, 1000ppr 광학식 엔코더 및 전자식 브레이크를 부하 변화량으로 채택하였다. 특히, 서보 구동부는 MOSFET 9540 및 540 FET를 사용하여 풀-브리지 방식으로 구동하였다. 서보 제어부는 8비트 PIC16C74 마이크로프로세서, RS-232 통신 포트 및 URD 전류 센서를 채택하였다. PID 방식을 기본으로 부하 변화량에 따는 다양한 계수 설정을 변화시키면서 제어 알고리즘을 적용하였다.

1. Introduction

The development of feedback control theory[8] and practical applications of servo control techniques has shown remarkable progress. Due to remarkable development of computers, it makes possible for servo control to implement machine action from the human's brain action composed of theory, computation and/or memory. Hence it causes drastic quality changes in servo control techniques. Although the motor driving system is partly controlled by conventional control, the development of computer make it possible to realize complex control system. And therefore it is necessary for servo control system to make available with semiconductor technology developing. Basically, brushed servo is applied for low-inertia load and low

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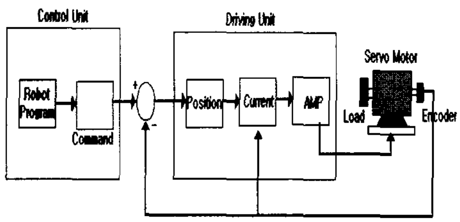
speed-torque characteristics. In this paper, industrial robot control system is composed of brushed servo motor, driving and control units. Brushed servo motor has 400W(40V and 10A) capacities and 1000ppr optic encoder. Brushed servo control systems have electric brake load which is changed by brake voltage from DC 12V to zero voltage and are controlled by PID control algorithms.

2. Structure of Servo Mechanism

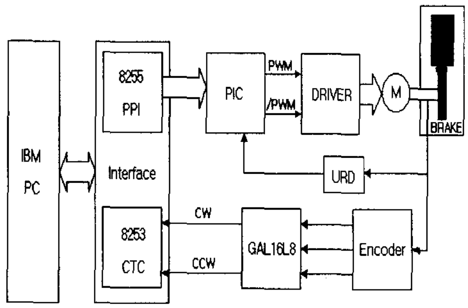
The review of Fig 1 shows the control and driving units of brushed servo system for high power industrial robot. Control units are composed of the main and sub units. The main unit of servo control system has GUI program which is made of visual C++ program, and PIC 16C74 microprocessor which is used for generating PWM driving and control signals, and detecting servo motor driving current from URD sensor.[4]



[Fig. 1] control system configuration

2-1. Control Unit

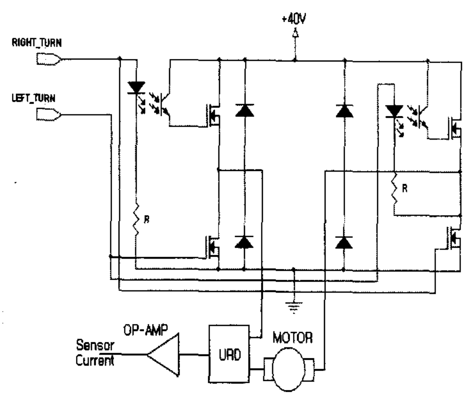
Control unit analyzes action command signals and converts control signals into driving signals. Command signal is the PWM signal which has about 20KHz frequency signal and is transferring to the full bridge FET driving units[9]. Control unit is activated by PIC 16C74 micro controller and serial communication function is acted by RS-232 for generating command signals with test mode experiment. Total control programs are composed of GUI program by visual C++ program[11,12] which is displaying the parameters and PIC assembly language which is communicating with driving units. The control unit has IBM PC, interfacing unit and one chip microprocessor, and the driver unit which are driver, current sensor and encoder parts as like the [Fig. 2.]



[Fig 2] Control Unit Configuration

2-2. Driving Unit

The driving unit actuates brushed servo system from the command of main controller in IBM-PC. The structure of driving unit of is the closed-loop control system as like the [Fig. 3][6,7]



[Fig. 3] Driver Configuration

Through [Fig. 3], servo driver circuit controller transfers the position, speed, and current signals to servo amplifier. And also the servo controller compares above signals with command signals, and reduces error information between command signals and measuring signals. For protecting driving units, TLP550 photo couplers are used. TLP550 constructs one chip photo diode transistor and is suitable for servo system at noisy environmental condition. Dual high speed power MOSFET drivers(TC4427) protected the driving units against up to 4KV of electro-static discharge. And also as MOSFET drivers, TC4427 can provide low enough impedances in both the ON and OFF states to ensure the MOSFET's intended state will not be affected, even by large transients.

2-3. Servo motor unit

Brushed servo motor is a permanent magnet servo motor which offers a performance range of 0.5 Nm to 37 Nm. Servo motor is fitted with a high precision optic encoder which has 1000ppr resolutions. Table 1 shows the characteristics of Brushed servo motor.

The rotary encoder has 1000ppr resolution which is line driver output method. The output signals are processed by GAL16R8 and transmitted to 8253 CTC un/down counters in the interfacing card.

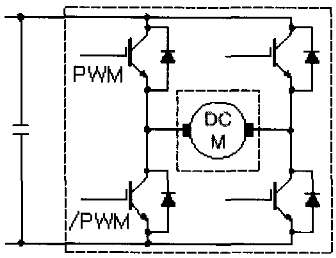
<Table 1> Charateristics of Brushed Motor

Parameter	Unit	Value
Max.Voltage	volts	95
Max.Speed	rpm	5000
Conti. Stall Torque	Nm	0.5
Amature Polar Moment of Inertia	kgm^2	0.00017
Torque Constant	Nm/Amp	0.18
Voltage Constant	V/s/rad	0.18
Peak Stall Torque	Nm	4.0
Armature Inductance	mH	8.2
Mech. Time Constant	mS	17

3. Modelling of Driver Circuits

3-1. Power Module Characteristics

[Fig. 4] shows the scheme of driver FET module configuration. Generally, power devices have the various structures that are following brief comparision between the structure of the npn BJT, MOSFET and IGBT. The npn BJT is a three junction device that requires a continous current flowing into the base region to supply enough charges to allow the junctions to conduct current. Because MOSFET and IGBT are voltage controlled devices, they only require voltage on the gate to maintain conduction through the device.[4,5]



[Fig. 4] Driver FET module

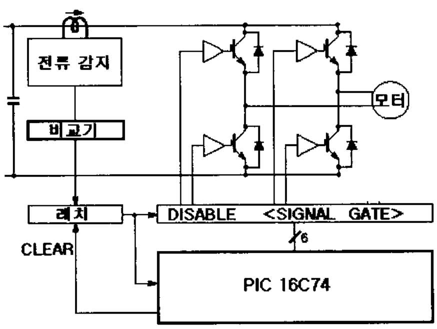
The MOSFETs have TO-200 packages and are both IRF540 and IRF9540. In this paper, MOSFET has the following characteristics as like <Table 2>.

<Table 2> Characteristics of MOSFET

Type	BV_{DSS}	$I_D(on)$	$R_{DS}(on)$	$P_D(W)$
IRF540	100(V)	28.00(A)	0.077	125
IRF9540	-100(V)	-19.00(A)	0.200	125

3-2. Short Circuit Protection

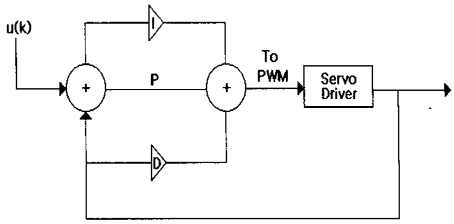
A short circuit occurs the stress on the power device remain within the SCSOA. Common methods of short circuit protection are current sensing and desaturation detection. Once a short circuit is detected, several techniques can be employed to protect the power device from destruction. The most elementary technique is to simply turn off the power device within 10ms. But, in this case, the snubber or clamp must be designed for the short circuit condition. However, It is recommended to use turn-off techniques that control the V_{CE} in order to reduce the stress on the power device. These techniques are displayed as like [Fig 5]. The gate voltage is reduced either in steps or by a ramp so that the short circuit current is reduced and its di/dt is also reduced as the MOSFET turns off. The spike voltage is also reduced. The peak of the short circuit current depends on V_{GE} which is augmented by the feedback of dv/dt through the gate-collector capacitance. The effect can be overcome by clamping the V_{GE} safely below 18 Volts. For reducing the thermal stress in short circuit operation it is benefiction to reduce the time in short circuit t_w. However, this will increase the magnitude of the current at turn off and di/dt will be increased. This undesirable effect may be overcome by using the above techniques.[9]



[Fig. 5] Short-Circuit Protection

3-3. PID Algorithm

The PID algorithm routine is not be the most optimum controller for all applications. The standard digital PID algorithm form is shown in [Fig. 6] U(k) is the position or speed error and y(k) is the output. Integrator windup is a condition which occurs in PID controllers when a large following error is present in the system. The integrator continually builds up during this following error condition even though the output is saturated. The integrator then "unwinds" when the servo system reaches its final destination causing excessive oscillation.



[Fig. 6] PID Algorithm Structure

The PID implementation shown in [Fig. 6] avoids this problem by stopping the action of the integrator during output saturation.[10]

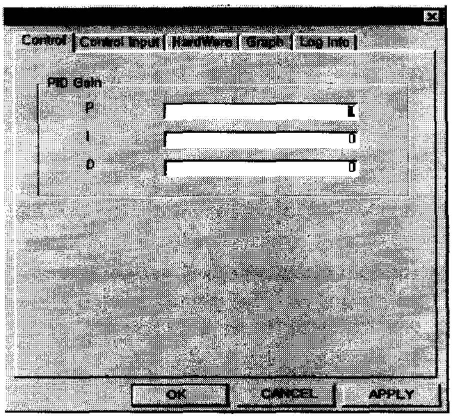
4. Experiments

4-1. Lab Setup Item

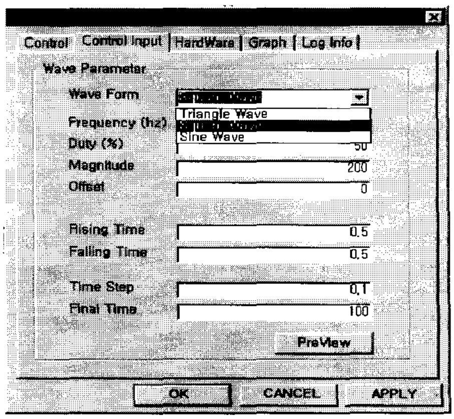
Lab Setup Item installs the actual experiment data. When we click the Lab Setup item, [Fig 7] is displayed by dialogue box and generated to the multi-page dialogues. Which of them are consisted of Control, Control Input, Hardware, and Graph, Log Info pages.

(1) Control Page

[Fig. 7] is the control page in the Lab Setup dialogue box. Control Page setups control gain for control method to the brushed servo motor control system. The initial gain is "0". When the every gain is "0", the brushed servo motor control system is treated to open loop control system.



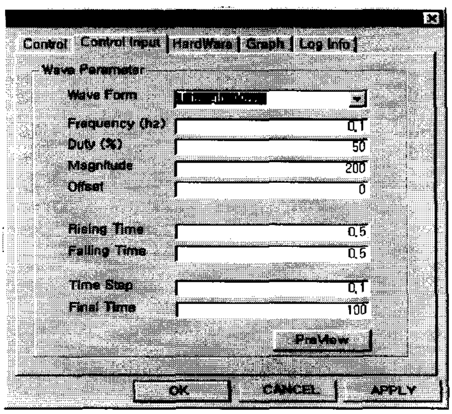
[Fig. 7] Control Page



[Fig. 9] Wave Form Items

(2) Control Input Page

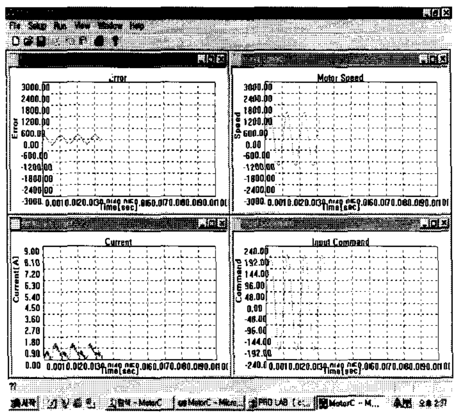
Control Input Page generates servo motor control input(command) to brushed servo motor control experiment. The servo motor control inputs are reference input waves for Triangle, Square, and Sine waves. Step input command generates rectangle wave. The parameters for input wave are the Frequency, Duty, Magnitude, Offset, Rising Time, Falling Time, Time Step, and Final Time. Each page is selected by selected wave forms whether active or not. [Fig. 8] is Control Input page. [Fig. 9] shows all input command wave forms. At the bottom of screen, Preview button shows preceeding wave forms according to parameter variations.



[Fig. 8] Control Input Page

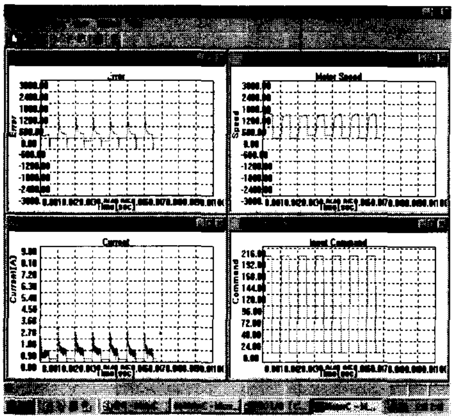
5. Experiment Result

Brushed servo motor control system is executed under the condition of PID control algorithm.[8] Through brushed motor control system, the experiment results are easily applied to the various industrial robot field.[9,10] When the control input command is sin wave and no-load condition with brake voltage is zero, [Fig. 10] is not applied PID control to brushed servo control system. In this case, servo control system has no load and is applied to open loop control method.



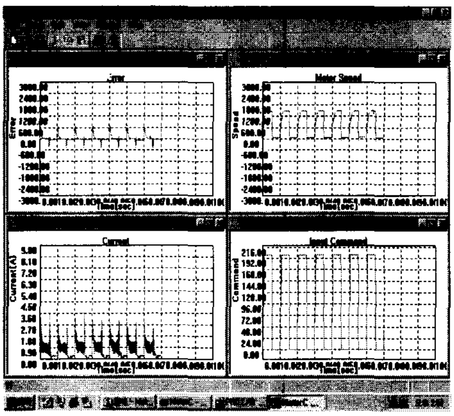
[Fig. 10] Input is sin wave

[Fig. 11] shows the system response of square wave command without the PID control, and the load brake voltages are 10V. As compare to [Fig. 10], [Fig. 11] has the higher driving current and error signals than no load condition because of load brake voltage.



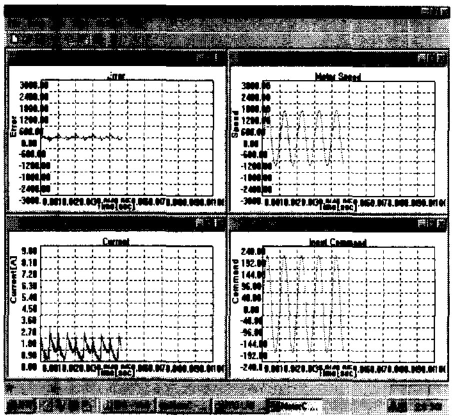
[Fig. 11] Input is square wave

When brushed servo control system is applied to the PID algorithm (K_p=0.1, K_I=0.01, K_D=0.05) under the square wave command, the error signal is remarkably reduced to the small value as like [Fig. 12]. But the load currents increase to the peak current to the 3.6A.



[Fig. 12] Input is square wave

When brushed servo control system is applied to the PID control algorithm (K_p=0.4, K_I=0.01, K_D =0.05) under the sin wave command, the error signal is remarkably reduced to the small value as like [Fig. 13]. But the load currents increase to the peak current to the 2.7A.



[Fig. 13] Input is sin wave

6. Conclusions

In this paper, we present brushed servo motor control system which improves performance of servo controller and driver units. Especially through tuning driver circuits, IRF type MOSFET driver semiconductors are used even though high power environments. The GUI program of servo control system is enable to control status of servo system parameters, and to display the speed, input type, current and error signals. The above functions are easily applied to the high power industrial robot and servo systems. Through this work, we proposed enhanced brushed servo control system. Afterwards, we are continuously applied to 2 and 3 axis industrial robot systems.

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