The Design of a Speed Regulator of DC motor Based on TMS320LF2407A and AT89C51

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***Abstract*—According to the requirements of a DC motor speed control system, a Dual-Closed-Loop Speed Regulator has been designed, with the AT89C51 and TMS320LF2407A is the MCU of this regulator. The function of TMS320LF2407A is sampling and regulating the speed of the DC motor, and the function of AT89C51 is inputting and displaying the speed of the DC motor. The hardware block diagram, program charts, and part of the program have been introduced in this paper. Experimental results have shown that this speed regulator had the advantages of fast dynamic response, high control precision, real-time display, data storage and strong anti-interference.**

Keywords- TMS320LF2407A; AT89C51; Real-time display; Data storage

I. INTRODUCTION

DC motor has always been used to the position control and speed control because of the good linear characteristics in spee-d control, the simple control performance and the high efficien-cy features smooth operation. Although the AC motor perform-ance has been deeply evolved because of VVVF-power re-cent years, but its speed regulator performance still can't com-pare with the DC motor.

Along with the appliance of micro-computer and power components, the pulse width modulation (PWM) control can be widely used to the domain of motor speed regulation. Compared to other controllers, DSP has advantages of high operational speed, fewer peripheral hardware etc, so it can be widely used in digital control of motors. In this paper, a digital DC motor speed regulator has been designed based on TMS320LF2407A and AT89C51; experimental results have shown that this regulator has advantages of real-time display, data storage, and fast dynamic response, high control precision and strong anti-interference.

II. HARDWARE DESIGN

The hardware block diagram of the closed-loop speed regul-ator based on TMS320LF2407A is shown in Figure 1. System main circuit is an AC / DC / AC voltage converters, and power device is the smart power module IPM. This IPM contains the four IGBT and four freewheeling diode which is anti-parallel connection with the IGBT. The control circuit is composed by AT89C51 control unit, TMS320LF2407A control unit, current detection circuit, speed detection circuit, over-voltage protecti-on circuit, under-voltage protection circuit, over-current protec-tion circuits, LCD circuits, and keyboard input circuit.

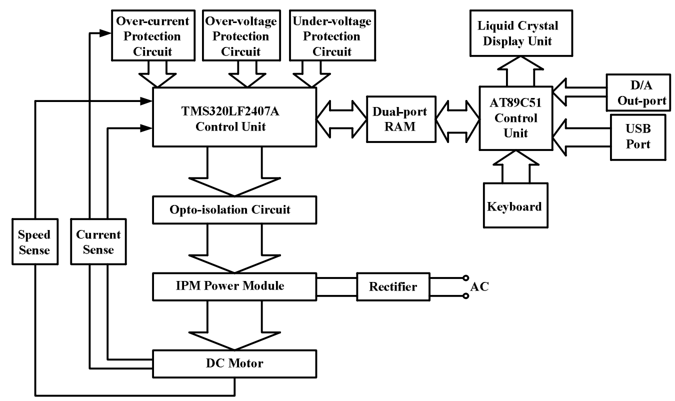


Figure 1. System hardware block diagram

A. *AT89C51 control unit* [1]

The following functions was realized by AT89C51 control unit: First, the input of a reference speed through the keyboard; Second the display of the reference speed, the motor starting s-peed and reach steady state speed by liquid crystal; Third readi-ng data from dual-port RAM or writing data to dual-port RAM; Fourth writing the data read from dual-port RAM to host com-puter by USB interface circuit or to the simulator by D/A outp-ut circuit.

The LCD display module isOCMJ4X8B-2; the keyboard is used to input the reference speed or choice Chinese characte-rs which has been stored in AT89C51; dual-port module is use-d to store the data of waveform which is sampled by TMS320-LF2407A [2] [3].

B. *TMS320LF2407A control unit*

The control circuit diagram based onTMS320LF2407A is shown in Figure 2. The control unit circuit includes four opto-isolation circuits, speed sampling circuit, current sensing circuit [4] and the voltage sampling circuit. And the functions such as over-voltage protection, under-voltage protection, over-current protection and speed control etc have been completed by this control circuit.

Opto-isolation circuit consists of four TLP127 and the co-rresponding current-limiting resistor, mainly to complete the f-unctions of the PWM signal amplification and the electrical isolation between TMS320LF2407A and Intelligent Power Module.

The 1024 rotating line Omron encoder E6B2-CWZ6C is used in the speed sampling circuit, after the output-pulse of encoder was multiplied four by TMS320LF2407A , then the pulse can be achieved 4096 pulses per revolution, thus the accuracy of speed control was ensured. According to the difference between the sampling-speed and the reference-speed, the width of output-pulse was adjusted by DSP, and then the voltage of DC motor was adjusted, so the speed of motor was regulated.

Current sampling circuit are two current sensor CN61M/-TBC25C04; one is used to sample the instantaneous DC bus current, which current compared with the reference current and decided whether the DSP shut down output-pulse; another is used to sample the motor current, so that this current is a constant when the motor's speed was regulating, thereby the output torque is a constant. The ports ADCIN00 and ADCIN01 of DSP is used to complete the function of current sampling circuit in this paper.

The port ADCIN02 of DSP is used to DC bus voltage sampling, when DC bus voltage is lower or upper the reference voltage, the output-pulse is shut down, then the function of over-voltage protection or under-voltage protection is completed.

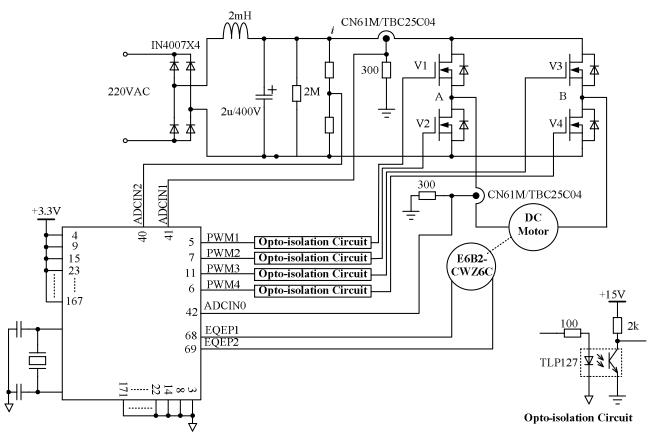


Figure 2. TMS320LF2407A control unit circuit diagram

III. SOFTWARE DESIGN

A. *The principles of closed loop speed control*

The block diagram of the closed-loop speed regulator is shown in Figure 3. The input of the reference speed is completed by the AT89C51 control circuit, and the speed PI regulator, current PI regulator and the speed feedback calcu-lation are completed by the TMS320LF2407A. The real-time sampling speed of motor is displayed by the liquid crystal display unit [5].

By the formula (1), we know when the DC armature voltage was regulated, the speed can be adjusted; By the formula (2),only the armature current was not regulated, the speed can be a constant. In this paper, the PWM control method was used to adjust the voltage of DC motor to regulate the speed.

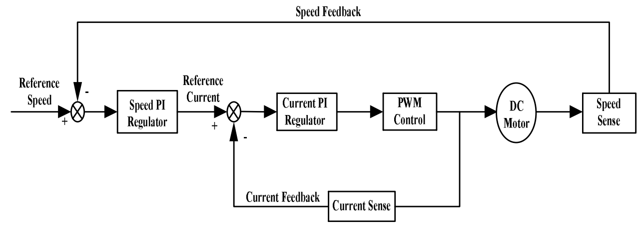


Figure 3. Block diagram of closed-loop speed control system

$$n = \frac{U_a - (I_a R + L\dfrac{dI_a}{dt})}{K_e \Phi} \qquad (1)$$

Of which: n is the motor speed; U_a is the armature voltage; I_a is the armature current; R is the total resistance of the armature circuit; L is the total inductance of armature circuit; K_e is the induced electromotive force constant ; Φ is the pole flux.

$$T_M = K_T I_a = T_L + J\frac{d\omega}{dt} \qquad (2)$$

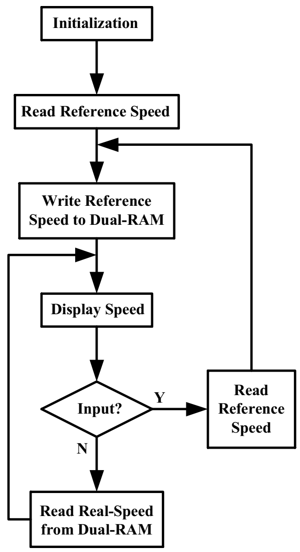
Of which: T_M is the motor electromagnetic torque; K_T is the motor torque constant; T_L is the load torque; ω is the motor angular velocity; J is the motor shaft inertia.

B. *Program flow chart*

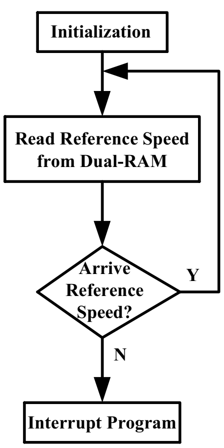
The function of the input of reference speed and the display of the real-time speed was completed by AT89C51 control circuit, which program flow chart was shown in Figure 4 (a). After power, the reference speed was read from the port P1 of the AT89C51, then this speed was written to the dual-port RAM., simultaneously, this reference speed was displayed by LCD display module, and the display range is 0 ~ 9999r/min. When TMS320LF2407A start work, AT89C51 first determine whether the reference speed changed; if changed, then this speed is written to dual-port RAM speed and displayed, otherwise, read the actual motor speed from the dual-port RAM and display.

The diagram of TMS320LF2407A main program was shown in Figure 4 (b). First the initial state settings (including the relevant variables sampling, data storage, etc.) was completed after initialization, and then read out a reference speed, and determine whether the actual speed reached the reference speed; if reached, then the output-pulse unchanged; if not reached, then the interrupt handling subroutine was run, the motor speed was regulated until the speed equal to the reference speed.

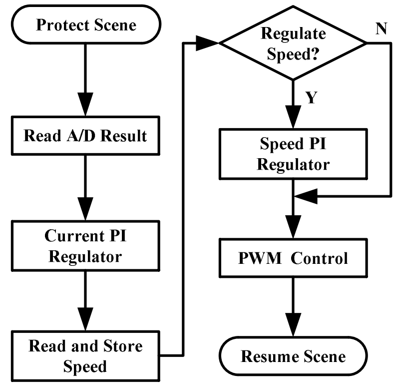
The interrupt subroutine flowchart was shown in Figure 4 (c) [6]. When the subroutine program was run, the sampling-current of DC motor was red from the dual-port RAM, this current compared with a reference current, and regulated by the method of PI. Then the speed of DC motor was sampled and stored in the dual-port RAM. If this speed wasn't equal to the reference, the speed was regulator by the method of PI, else, the duty of PWM pulse was changed, and then the subroutine program was ended.



(a)AT89C51 process flow diagram



(b)TMS320LF2407A main program flow chart

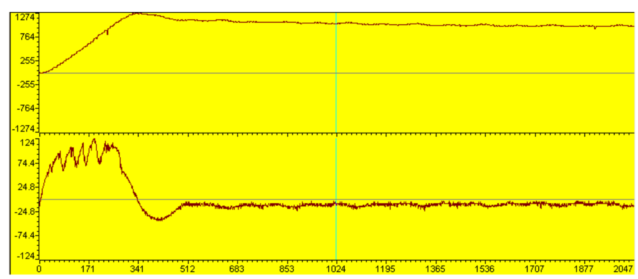


(c)interrupt subroutine flowchart

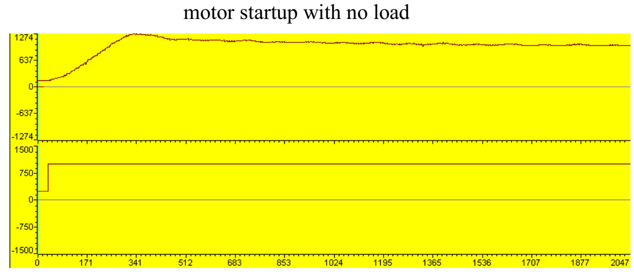
Figure 4 Program flow chart

IV. THE RESULTS OF EXPERIMENT

When there isn't load, the feedback speed of DC motor and the current of the stator of DC motor were sampled. The sampling-data was input the host computer through USB port, and the waveform (shown as Figure 5 (a) and (b)) were plotted by computer. In Figure 5, the horizontal axis is the timeline; the data sampling period was 0.01s. It has been shown in the experimental waveform; in a short time (about 20s) the speed of motor reached 1000r/min, which was the reference speed. In the startup process, the stator current had some fluctuations because of PWM control, but when the speed reached the reference speed, the stator current has quickly been stabilized.



（a）the feedback speed waveform and the stator current waveform when motor startup with no load



(b) the feedback speed waveform and the reference speed waveform when the motor was accelerated suddenly

Figure 5 Experimental waveforms

When the motor is running, changing the speed (for example to accelerate the speed from 100r/min to 1000r/min), then sampling the reference speed and the feedback speed, the sampling-data was transferred to the PC , the waveform was plotted as shown in Figure 5(b). It could be concluded from the waveforms of experiment that the actual speed reached the reference speed—1000r/min within 4s, the speed fluctuation was only 9r/min, control precision was high, meet the design requirements.

V. CONCLUSION

In this paper, a Dual-Closed-Loop Speed control system has been designed, with the AT89C51 and TMS320LF2407A is the MCU of this regulator. This control system has the function of data-storage and real-time display, experimental results shown that the control system had advantages of fast dynamic response and high control accuracy etc. It has been proved in practice that the system also had good anti-interference. The system also had a high significance to the motor control system design and implementation.

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