Research on DC Motor Control Based on PWM Technology

Gang Wu[1, a], Wen Yang[2, b]

[1]College of Intelligent Manufacturing, Pan Zhihua University, Pan Zhihua, China

[2]Intelligent Manufacturing, Zhihua University, Pan Zhihua, China

[a]wugang_d@126.com, [b]wugang_d@126.com

Keywords: PWM technology, DC motor control, Research.

Abstract: PWM technology is a technology that converts input voltage signal into pulse signal with adjustable width by using on and off of fully controlled power electronic devices to realize frequency conversion, voltage conversion and harmonic elimination. Therefore, based on the control principle of PWM, the hardware driving circuit and software programming of DC motor are designed to realize the control of forward, reverse, speed-up, speed-down and stop of DC motor. This research will be widely used in robot design, UAV control, artificial intelligence and so on.

1. Introduction

PWM technology is a technology that converts the input voltage signal into a pulse signal with adjustable width by using the turn-on and turn-off of fully controlled power electronic devices to realize frequency conversion, voltage conversion and harmonic elimination. Based on the characteristics of PWM technology, when designing the hardware circuit and software of the control system of DC motor, the control system can guarantee to supply power to DC motor with different frequency and different pulse width (different duty cycle), thus realizing the control of DC motor such as forward, reverse, speed up, speed down and stop. Therefore, the research of DC motor control system based on PWM technology is of great significance to the development of artificial intelligence[1].

2. PWM Control Technology

2.1. Basic Principles of PWM Control Technology (Area Equivalence Principle)

The basic principle of PWM control technology is area equivalence principle. Its specific equivalent process is as follows: Fig. 1 (a) shows that the sinusoidal half-wave is divided into N equal parts. It can be regarded as N series pulses with equal width and different amplitude, which are replaced by rectangular pulses with equal amplitude and different width when the area (impulse) is equal. The width of the pulse varies according to the sinusoidal law, as shown in Fig. 1 (b). It can be seen from Figure 1 that to change the equivalent output sinusoidal wave amplitude, only the pulse widths need to be changed in the same proportion, which is equivalent to replacing the sinusoidal half-wave with the PWM pulse width modulation waveform[2]. This is to realize the generation of PWM (pulse width modulation signal) by using the area equivalence principle. If the PWM waveform is input into the DC motor drive circuit, the motor speed can be controlled [3].

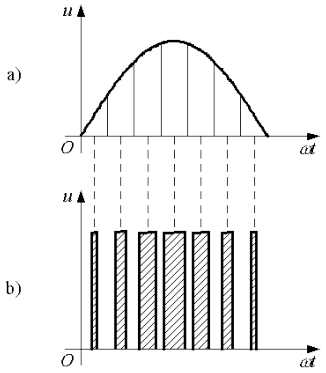

Fig.1. Replacing sinusoidal half-wave with PWM wave

2.2. Single-phase Bridge PWM Inverter Circuit

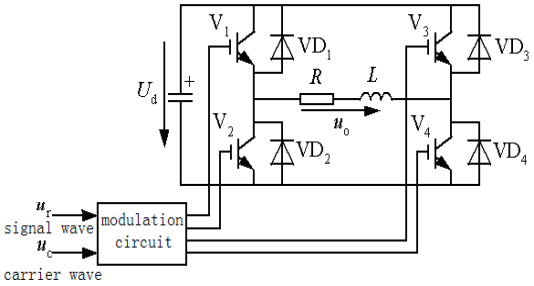

Fig.2. Single-phase bridge PWM Inverters Circuit

Fig. 2 is a single-phase bridge PWM inverter circuit, in which u_r is a sinusoidal modulation signal and u_c is a triangular wave carrier signal. In the circuit, when $u_r > u_c$, the high level of the output of the modulation circuit turns on V1 and V4, and the low level of the output signal turns off V 2 and V3. At this time, t the output voltage of the RL branch is expressed as follows[4]:

When$u_r < u_c$, the high level output of the modulation circuit turns on V2 and V3, and the low level output signal cuts off V2 and V3. At this time, the output voltage of the RL branch is expressed as follows[5]:

$$u_0 = -U_d - 2U_{ce} \approx -U_d$$

Thus, the bipolar PWM signal as shown in Figure 3 can be obtained from (1), (2) expressions.

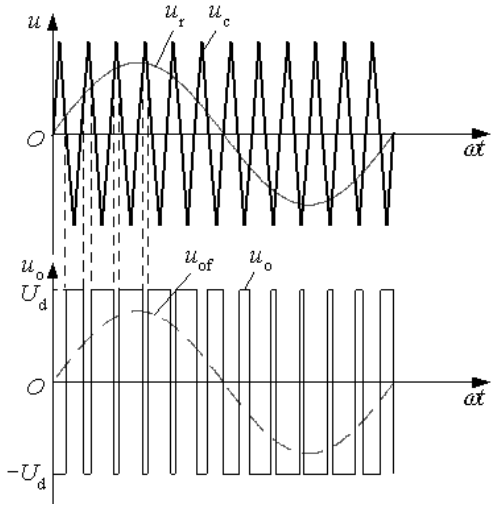

Fig.3. Bipolar PWM waveform

$$u_0 = U_d - 2U_{ce} \approx U_d.$$

3. Design of Hardware Driving Circuit for DC Motor

3.1 PWM Speed Regulation Principle of DC Motor

The PWM speed regulation principle of DC motor is that when the PWM pulse signal frequency of the input DC motor is constant, the effective voltage value of the input DC motor can be indirectly changed by changing the duty cycle of the pulse signal （$\alpha = \frac{T_{ON}}{T} = FT_{ON}$）, thus the speed of the motor can be changed. The higher the duty cycleαis, the higher the effective value of voltage input to DC motor will be, and the faster the motor speed will be. On the contrary, the smaller the duty cycleα is, the slower the motor speed will be. When the duty cycle is $\alpha = 0$, the motor will stop running. When the polarity of voltage added to both ends of the DC motor is changed, the direction of rotation of the motor will be changed. The DC motor speed control circuit controlled by single chip computer is shown in Fig. 4[6].

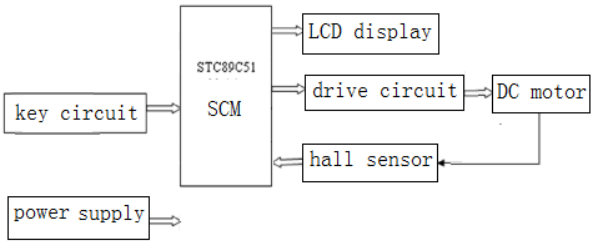

Figure 4. DC motor speed control block diagram

3.2 Design of Hardware Driving Circuit for DC Motor

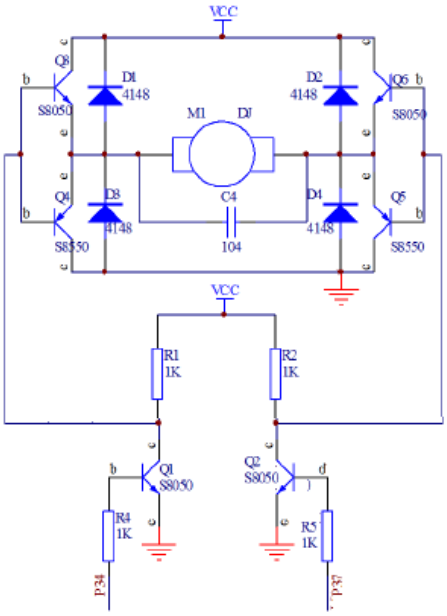

Fig. 5. DC motor drive circuit

As shown in Fig. 5, in order to realize PWM control technology by software programming, H bridge motor drive circuit is adopted here, and the modulation circuit in Fig. 2 is replaced by a single chip computer. In Fig. 5, the base of driving transistors Q1 and Q2 are connected to the P3.4 and P3.7 of the single chip computer respectively. The PWM signal output by the single chip computer is used to control the rotation of the motor. The specific principle is as follows: when P3.4 outputs high level and P3.7 outputs low level, the transistor Q1 turns on and Q2 cuts off, so that the transistor Q3, Q5 cuts off and Q4, Q6 turns on in the motor drive circuit, so the current flow direction of motor M1 is: VCC→Q6 →M1→Q4 → ground, making motor M1 rotate forward. Regulating duty cycle of P3.4 output PWM signal can adjust positive speed of motor; conversely, When P3.4 output low level,and

P3.7 output high level, the transistor Q1 cut off, Q2 turn on, in the motor drive circuit, the transistor Q3, Q5 turn on, Q4, Q6 cut off, the current direction of motor M1 is: VCC Q3 M1 Q5 ground, motor reverse. The reverse speed can be adjusted by adjusting the duty cycle of the output PWM signal of P3.7. When P3.4 and P3.7 output low level at the same time, the motor M1 will stop running[7].

4. Software Programming Generates PWM Signals

The output level of single chip microcomputer P3.7 and P3.4 is realized by software programming. The system software design is mainly composed of main program, motor duty ratio setting value sampling subprogram, PWM duty ratio display subprogram, DC motor control subprogram and T0 interrupt service subprogram. For the main program of the system, the design flow is shown in Fig. 5.The main functions of the program are as follows:(1) Complete system initialization, set stack and timer T0, set timer T0 to work in mode 2, initial value of THO and TLO is 0xce; (2) Allow total interrupt and T0 interrupt to start timer T0; (3) Read the operation mode of the system. The starting, stopping, forward and reverse setting requirements of DC motor are obtained, and the sampling subprogram of duty cycle setting value is invoked, and the set duty cycle of DC motor is sampled five times and converted into A/D; (4) The arithmetic average filtering algorithm is used to filter the sampled data, and the data processing subprogram is called: (5) Call the PWM control subprogram of DC motor. PWM wave is output through PC 3.4 and P 3.7 of single chip computer. The speed regulation and steering control of DC motor are realized[8].

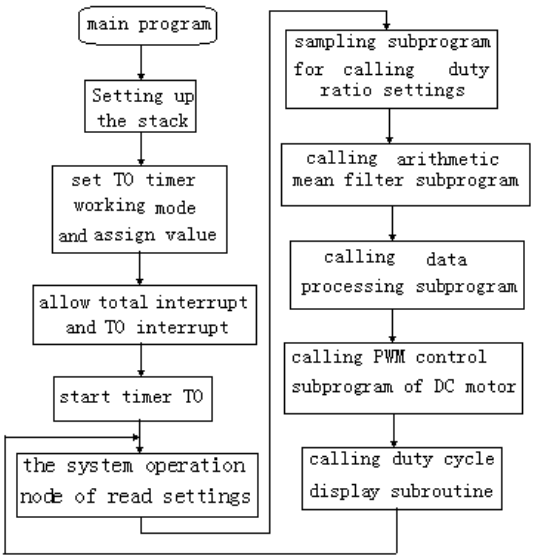

Fig. 6. Main program flow chart

5. Motor Speed Automatic Tracking and Regulation Control Technology

5.1. PWM Tracking Control Technology

PWM tracking control technology is to compare the feedback signal detected by Hall element with the standard signal input comparator. The output signal of the comparator determines the on-off condition of the inverting circuit device, thus realizing the control process of tracking the change of the instruction signal of DC motor. At present, hysteresis comparator and triangular wave comparator are commonly used.

5.2. Speed Tracking Control Technology of DC Motor Driven by Single Chip Microcomputer

The DC motor tracking technology controlled by single chip computer replaces the hysteresis comparator in the current tracking control mode by the programming technology of single chip computer. Its composition block diagram is shown in Fig. 4. The specific principle is as follows: Hall sensor detects motor speed, Hall element sends the detected pulse signal to MCU, the frequency of

the pulse signal is proportional to the motor speed, and the speed can be calculated by measuring the period or frequency of the pulse. Through software programming design, the single chip computer calculates and processes the speed information input by Hall sensor, and forms a PWM control signal with adjustable pulse width. The speed of DC motor is adjusted by driving circuit, so that the purpose of automatic tracking of motor speed is realized.

6. Conclusion

From the above research on DC motor control using PWM technology, it can be seen that, under the condition of ensuring the hardware circuit design of the system, the duty cycle of pulse width signal is changed by software programming, which not only generates PWM signal, but also restrains the harmonic component in the output voltage of the inverter. Accurate control of DC motor such as forward, reverse, speed-up, speed-down and stop has been realized. Therefore, the study of PWM DC motor control technology is of great significance to the development of "artificial intelligence" technology.

References

[1] L. H. Hong, “The Proteus-based simulation design of liquid temperature display”, Electronic Design Engineering, 2011。

[2] T. Q. Cao and J. P. Xu, “Design of digital DC driving system based on DSP”, Power Electronics, 2008.

[3] Z. H. Zou, C. Wu, and Q. J. Zeng, “PWM speed regulation system for DC motor based on SC2410”, Microcomputer Information, 2008。

[4] Z. J. Yuan, “Research on PWM regulating speed system of DC motor based on Proteus”, Electronic Design Engineering, 2013.

[5] F. H. Li, Electrical Engineering ,5th ed, Science Press,Beijing, 2013..

[6] H. G. Kang, Digital Circuit Technology Base, Beijing:Advanced Education Publishing House, 2000.

[7] H. Q. Tan, C, language programming ,4th ed, Beijing;Tsinghua University Press, 2010..

[8] K. Y. Xian, “Based on PWM dc motor control system design”, Journal of Foshan Institute of Science and Technology, 2000.