

Design and Research on Vehicles Motor Testing System Based on Improvement PID

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Abstract: Motor is the important parts in vehicles. It is the key parts for achieving automation. It is the critical technology to test vehicle motors. We take the PID (Proportion Integration Differentiation) as based fundamental controlling algorithm, and we test motor parameters through LabVIEW for single-chip AT89C52. According to practical working condition, we build circuit electric field boundary, and analyze electric field distribution of hard circuit. In addition, we also design filtering circuit for main interrupt frequency (below 1 kHz), and we improved PID for direct motor speed which is controlled by PWM (pulse-width modulation) to reach speed astatic regulation. At the same time, the system achieves soft start-up. Copyright © 2014 IFSA Publishing, S. L.

Keywords: Vehicles motor testing system, Improvement PID, PWM, LabVIEW.

1. Introduction

The motor is one of the important and key parts in automotive electronics and has achieved the automatic control of car window, rear view mirror wiper and trunk, which is one of the indispensable equipment. The DC motor is used for motor vehicles, which is one of the first equipment to achieve speed regulating. During the past decade, The DC motor speed control has been occupying the dominant position. It has good characteristics of linear control, simple, high efficiency, excellent dynamic, which is still the optimal choose for speed control of motor. In order to ensure the quality of motor, we need the good performance of test equipment [1]. It has important significance to test control system of the DC motor. Although a lot of effort is being spent on improving these weaknesses, the efficient and

effective method has yet to be developed. At present, there are many literature and patent about motor test in domestic and international research. The representative has many, such as the patent of America. Kevin I. Bertness [2], Terry Castle, Tiffany Kasettratut, Richard McDonald [3], and the network testing system, which was designed by Zhou Jian, Chen Longdao in China [4], etc.

With the development of SCM, the PID control theory and the digital DC PWM speed control system have been widely used in industry. The control method has also been increasingly improved, and the development of the virtual instrument technology has poured into the new vitality for it [5, 6]. This paper includes an illustration of the PID as the basic control algorithm. The PC is designed by LabVIEW [7] and AT89C52 single chip microcomputer as the core [8]. The host computer achieves the digital PID

algorithm [9]. Lower machine implements speed control by PID output pulses which produces the duty ratio. The motor speed is got feedbacks to the control system by photoelectric sensor [10-15]. The basic questions posed above are then discussed and conclusions are drawn. It achieves the control of speed in closed-loop. At the same time, the system eliminates the impact and interference when starts by the traditional mode, which implements soft start-up and stop.

2. Design of PC based on LabVIEW

The LabVIEW program is composed of front panel and block diagram. The front panel is man-machine interaction interface with the user to input and display. The block diagram is the program source code by the user to define the input and output function on the front panel. Fig. 1 is the human-

machine interface, which is mainly composed of the speed input module, display module, communication module, PID control module and control module. The configuration and the PID control module, serial communication module will be described in the following section.

2.1. Serial Communication Module Configuration

The design of serial communication program in LabVIEW is based on the VISA. The used modules of VISA include serial port initialization, read, write and close. When in use, we must set the serial port resources, baud rate, data bits, stop bits, parity and other parameters through serial port initialization module. In order to ensure the proper use of serial port, the value should be consistent with the lower computer.

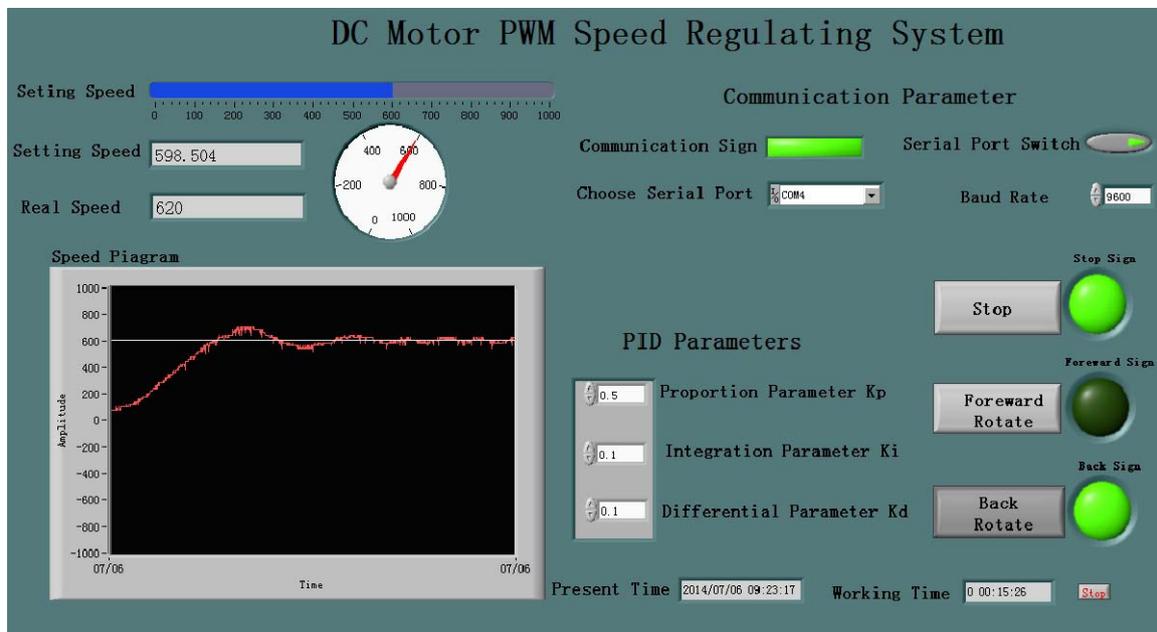


Fig. 1. LabVIEW interactive interface.

2.2. Design of PID Control Module

In order to improve the regulation performance of PID, many PID VI derived from PID toolkit on the basis of PID, such as advanced PID VI, PID VI with gain schedule, PID VI with functions of self-adjusting, etc. This system adopts the basic PID VI in LabVIEW to improve the speed control system. The input of module is the value of set speed and the measured actual speed. The output value is the duty ratio signal PWM wave. The normal form of PID controller is:

$$u(t) = K_p \left[e(t) + \frac{1}{T_I} \int_0^t e(t) dt + T_D \frac{de(t)}{dt} \right], \quad (1)$$

where K_p is the proportion coefficient, T_I is the integral time constant, T_D is the differential time constant. The setting parameter is very important. The stability of the system depends on the three parameters of P, I, D.

3. Design of Lower Computer Circuit Based on Proteus

3.1. Hardware Circuit Design

The AT89C52 single chip computer of lower machine is designed by Proteus 7.0. The hardware circuit is shown in Fig. 2. AT89C52 micro controller

as the core and the speed detection module as motor speed measurement device are presented and justified. Electric pulse signal inputs the machine for processing through the P0.2 port and P3.2 port of AT89C51. The output signal from P0.0 port and P0.1

port suggests as the DC motor drive module in L298, L298. It communicates with the host computer by RS-232 interface. The system has also presented the clock circuit, reset circuit and power supply circuit.

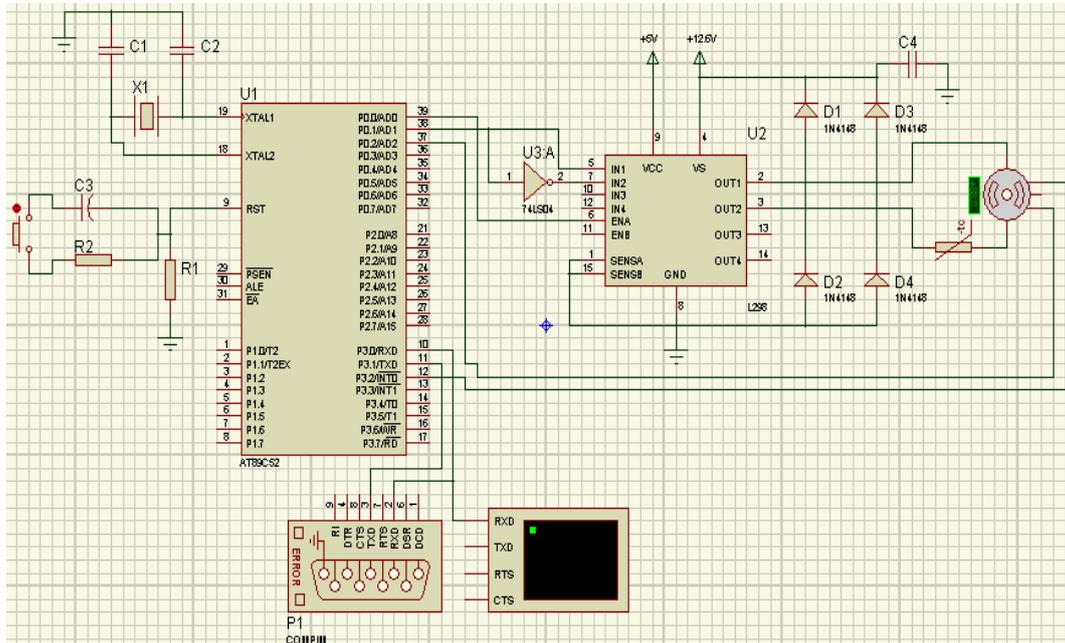


Fig. 2. The hardware circuit of system.

The system demonstrates the rotation speed of motor by counting number of encoder output pulse within 50 ms. The judgment of steering is determined by count pulse number from encoder in the P0.2 port, P3.2 port. Photoelectric encoder integrated with DC motor, which can be seen the same as DC motor and photoelectric encoder is coaxial transmission. In the practical use, the transmission between encoder and motor is coaxial or through gear. Grating disc rotation of encoder drives the rotary of motor, and then through the photoelectric detection device in encoder outputs several of detection pulse signal. In general, each encoder has a rated resolution, namely, the pulse number within the encoder to rotate a week. Therefore, the rotational speed of motor can be calculated by outputting pulse number of the encoder and the encoder resolution. Assuming the motor and encoder is coaxial transmission, and the encoder resolution is p , the output pulse number is m within t second period, the speed n of motor can be calculated as follows:

$$n = m/pt, \quad (2)$$

3.2. Analysis of Electromagnetic Disturbance of Circuit

The vector design of hardware circuit exists along the electric field outward and perpendicular to the

field. Therefore, the boundary condition is the mixed boundary condition (namely, Dirichlet and Neumann).

The Dirichlet boundary condition is $hu = r$;

The Neumann boundary condition is

$$n \cdot (c \nabla u) + qu = g,$$

where n is the unit normal vector of $\partial\Omega$, g, q, h and r are the reference function of $\partial\Omega$. For solving the eigenvalue problem, this paper is limited to homogeneous condition $g = 0, r = 0$. However, for the nonlinear case, coefficient g, q, h can dependent on the coefficient u . For equations case, Dirichlet boundary condition can be expressed as the formula (3):

$$\begin{cases} h_{11}u_1 + h_{12}u_2 = r_1 \\ h_{21}u_1 + h_{22}u_2 = r_2 \end{cases}, \quad (3)$$

The Neumann boundary condition can be expressed as the formula (4):

$$\begin{cases} n \cdot (c_{11} \nabla u_1) + n \cdot (c_{12} \nabla u_2) + q_{11}u_1 + q_{12}u_2 = g_1 \\ n \cdot (c_{21} \nabla u_1) + n \cdot (c_{22} \nabla u_2) + q_{21}u_1 + q_{22}u_2 = g_2 \end{cases}, \quad (4)$$

The mixed boundary condition can be expressed as the formula (5):

$$\begin{cases} h_{11}u_1 + h_{12}u_2 = r_1 \\ \mathbf{n} \cdot (c_{21}\nabla u_1) + \mathbf{n} \cdot (c_{22}\nabla u_2) + q_{21}u_1 + q_{22}u_2 = g_2 + h_{12}\mu \\ \mathbf{n} \cdot (c_{11}\nabla u_1) + \mathbf{n} \cdot (c_{12}\nabla u_2) + q_{11}u_1 + q_{12}u_2 = g_1 + h_{11}\mu \end{cases} \quad (5)$$

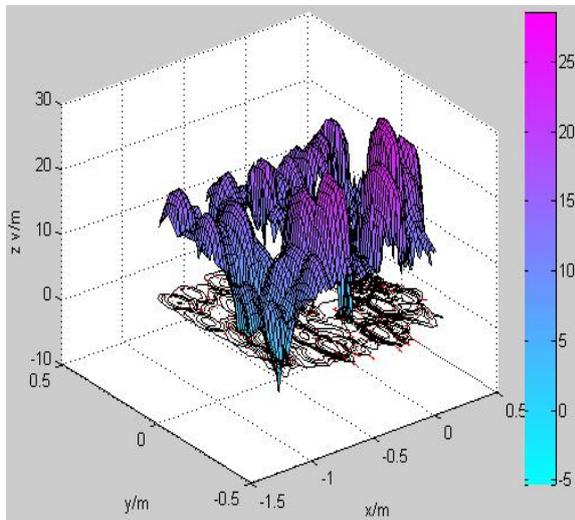


Fig. 3. Hardware circuit electromagnetic radiation.

The calculation process of coefficient μ must well meet the Dirichlet condition.

r_1 and r_2 respectively represents the boundary voltage. After testing, the instantaneous maximum value of boundary voltage is 8.6 V. The maximum instantaneous value of motor voltage is 5.6 V. The maximum instantaneous value of resistor and diode is 3.6 V. After setting the boundary condition, the electromagnetic radiation intensity image indicates the actual circuit board, and as shown in Fig. 3, The

voltage change is obvious around the motor. The electric field intensity is strong. Because of the rapid change of voltage, the electric field intensity of single chip microcomputer is also bigger. It can be seen from the image that the layout of circuit must be away from high field position, which improves the stability of device.

3.3. Analysis of Filter Circuit

The active filter circuit has characteristics that input resistance is high and output resistance is low. As a consequence, it does not affect the filtering properties and suitable for signal processing. Motor testing field is mainly affected by the 1 KHz interference. Therefore, the paper proposed the design of high pass filter circuit. The parameter settings are as follows: cutoff frequency is 1 kHz, the amplitude is -200 dB-100 dB, the group delay is 0-3.2 us, the phase is -200-200 Deg, the ramp response is -0.00006-0.00008 s, the step response is -0.4-1 s, impulse response is -10000-4000 s. According to the requirements of the circuit parameters, three orders Butterworth high-pass filter circuit is designed. The filter circuit is shown in Fig. 4. The overall performance of circuit is stable. The response is shown in Fig. 5. In Fig. 5(a), when the frequency is lower than 1 kHz, group delay is higher. It is about 330 Hz, whereas, the group delay gradually reduces to 0, and the reaction time is faster. In Fig. 5 (b), step response, impulse response and ramp response are stable within 3 kHz.

The circuit transfer function is shown in equation 6:

$$F(s) = \frac{s^3}{s^3 + 1.257 \times 10^4 s^2 + 7.896 \times 10^7 s + 2.481 \times 10^{11}} \quad (6)$$

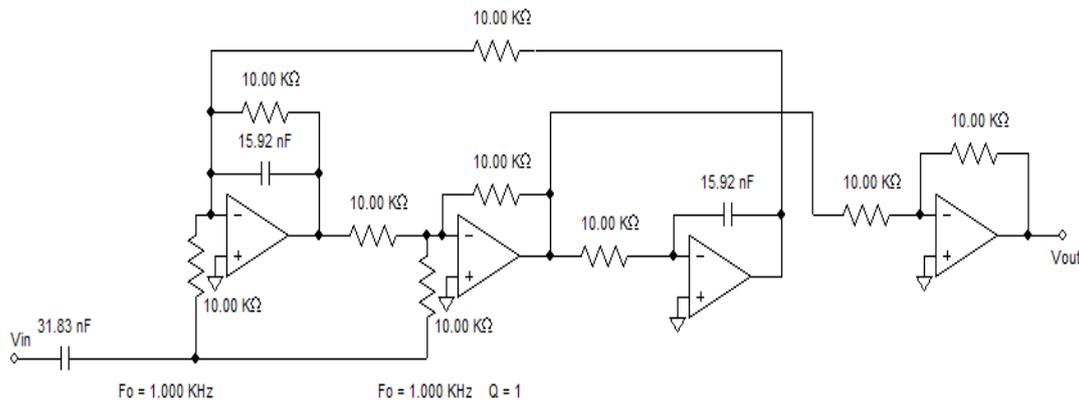


Fig. 4. Filter circuit design.

4. The Test

In order to meets the requirements of the system, testing and analysis of this problem is presented under the assumption that the sampling rate decision can be made prior to the execution of

the experiment, as opposed to being made while the experiment is in progress. However, owing to the restriction of trial adjustment and time limit, it can only be verified by simulation. It is simulated based on LabVIEW, Proteus and VSPD software. The parameters setting dialog box of the COMPIM

module are as follows: the physical serial port settings is the COM3, baud rate is 9600, and data bits is 8 bits, stop bits is 1 bit, no parity. In the setting dialog of AT89C52, after loading code compiled successfully, the clock frequency is set from 12 MHz to 11.0592 MHz. In this case, the

system can be considered to be generative. As a result, when the communication baud rate is 9600 bps, there is no accumulated error, and the performance of communication is synchronization with PC.



(a) Frequency response



(b) Time response

Fig. 5. Filter circuit response.

In communication parameters of the front panel, serial sets the COM4, baud rate is 9600. Other communication parameters adopts default values, namely data bit is 8 bits, stop bits is 1 bit, no parity. The above preliminary analysis has provided important information. It has been proposed for selecting different parameters for simulation and testing. In the following section illustrates the whole steps of experience method with an example of PID regulator:

1) The controller parameter setting of integral coefficient $K_I=0$, The actual differential coefficient $K_D=0$, The control system operation on Closed-loop, To change the proportion coefficient K_P until satisfactory, The disturbance signal is step change;

2) The proportion coefficient K_P for the current value is multiplied by 0.83, then increases the integral coefficient K_I , the disturbance signal is also step change;

3) The integral coefficient K_I remains unchanged, changes the ratio of coefficient K_P , Debugging to the system until satisfied. Otherwise, increases the original proportion coefficient K_P , and then changes the integral coefficient K_I , repeatedly, until the system well meets the requirement;

4) The introduction of the differential coefficient K_D and practical differential time T_D is appropriate, we can repeatedly increase the proportion coefficient K_P and integral

coefficient properly K_I until the system well meets the requirement.

The PID parameter is determined by the inertia of controlled object. About large inertia, such as: temperature control of large drying room, generally, P is above 10, I is between 3 and 10, D is about 1. About small inertia, such as: a small motor is controlled by closed-loop, generally, P is between 1 and 10, I is between 0 and 5, D is between 0.1 and 1. The specific parameters will be revised at the debugging scene.

According to the method, the simulation data is shown in Table 1. Therefore, the parameter value of P, D and I are: $K_P=1.0$, $K_I=0.05$, $K_D=0.1$.

Table 1. Test data.

Times	K_P	K_I	K_D	Rotational Speed (r/min)	Overshoot	Adjusted time (s)	Error (r/min)
1	4	0	0	600	12%	61	± 5
2	2	0	0	600	11%	60	± 3
3	1	0	0	600	10%	58	± 2
4	1	1	0	600	4%	183	± 3
5	1	0.5	0	600	7%	60	± 4
6	1	0.1	0	600	11%	55	± 6
7	1	0.1	1	600	5%	276	± 1
8	1	0.1	0.1	600	6%	52	± 2
9	1	0.05	0.1	600	7%	51	± 4
10	1	0.05	0.05	600	11%	50	± 5

In addition, it illustrates the function of various correction links in PID regulator is:

1) The proportion of link: the response speed of system is decided by the value K_p . It improves the response speed and decreases the steady-state error with increase K_p . However, there will overshoot congress when the value is too big, the system is unstable. We can reduce the overshoot to increase stability. Whereas, the system will reduces the speed of response and prolongs the adjustment time when the value K_p is too small;

2) The integral of link: it mainly is used for eliminating the static error and improving indiscrimination degree. The result depends on the integral time constant T_I . When T_I is larger, the integral effect is weaker. Whereas, the integral effect is more strong;

3) The differential link: it reflects the change trend of deviation signal. The effective correction of signal was introduced before the deviation in the

signal value is too high. Thus, the system movement speed is improved and reduced the adjusting time.

After the testing, when K_p is 1, K_i is 0.05, K_d is 0.1, the system simulation is shown in Fig. 6.

We can see from Fig. 6, the system achieves the reversible speed. However, when the speed is big, owing to have a large impact on the power supply and system, the system is not suitable to shift. Analyze the effect of NTC on the soft start with current probe in the power supply circuit of the motor. The analysis of motor start is shown in Fig. 7.

As shown in Fig. 7 (b), when the power supply circuit is not concatenation with NTC, the maximum current of startup power supply circuit is 4.0 A. As shown in Fig. 7 (b), whereas, the maximum current is 1.65 A. From the results obtained so far, it seem that when the power supply circuit is concatenation with NTC, the starting current is limited in allowable range. In addition, it can effectively reduce the mechanical shock to the system.

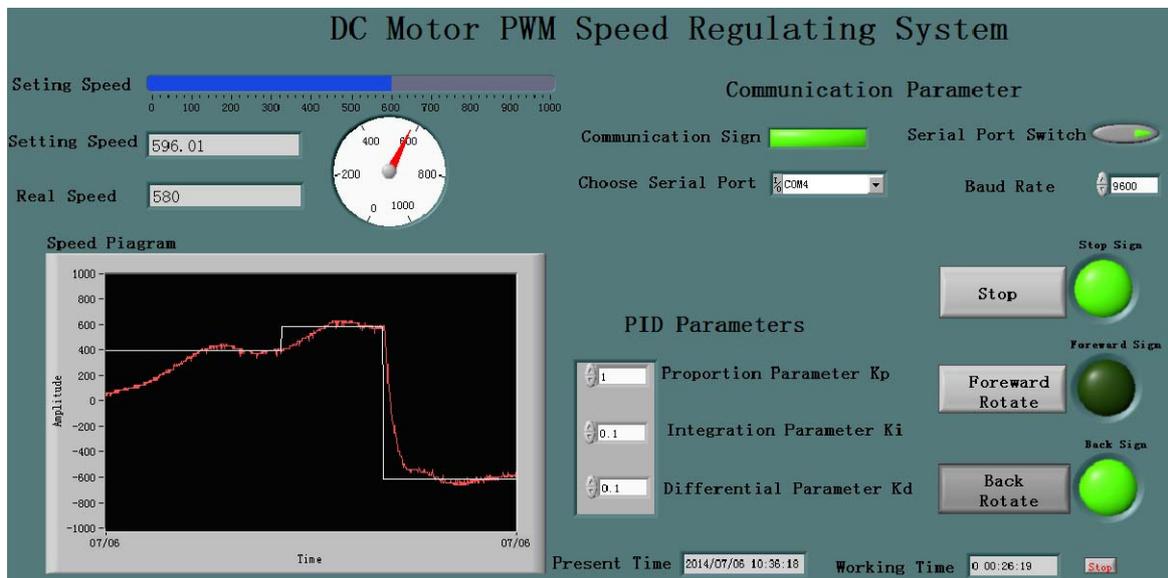
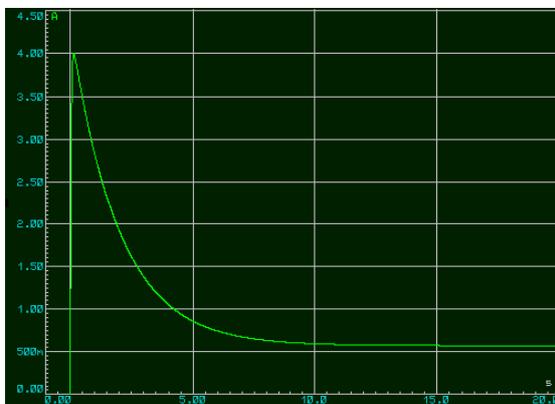
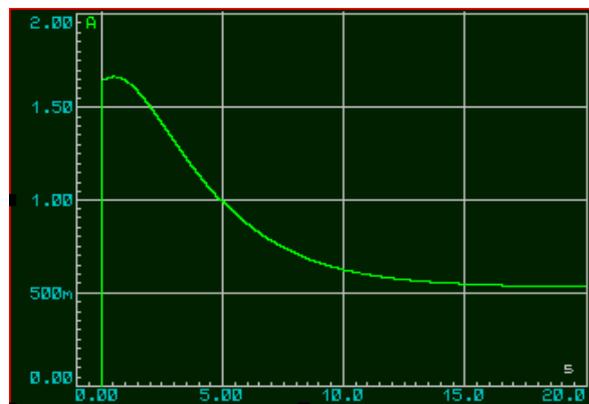


Fig. 6. System simulation.



(a) No tandem connection NTC resistance



(b) Tandem connection NTC resistance

Fig. 7. The analysis of motor start.

5. Conclusions

This paper has presented an automobile motor test system based on LabVIEW, The experimental results reveal the motor test visual operation and speed testing with no static error. At the same time, the reversible motor control has been achieved. We test motor parameters through the design of MCU circuit. According to practical working condition, this paper proposed the design of boundary condition to analyze the electromagnetic radiation, and have attempted to introduce the concrete improvement measures associated with electromagnetic radiation. Owing to the strong interference, this paper analyses problems in the major sources of interference frequency. The main frequency is 1 KHz, and then the filter circuit is designed to improve of PID control. The experimental simulation results show that the system well meets the requirements. The motor testing system has a good market application prospect, which can be used as a component testing equipment of automobile manufacture.

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