



PID Based Automotive Electronically Controlled Power Steering System in the Internet of Things Environment

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Abstract. It is difficult to adjust parameters automatically to obtain the optimal control parameters, and the steering performance of the system is often not ideal. In order to solve this problem, this paper designs an automotive electronic control type power steering system based on PID under the Internet of Things environment. A switching step-down circuit is composed of a combined power supply mode, and then the drive circuit is designed, and the output end is flexibly configured through the control pin. In the software design part, the vehicle system dynamics model is established by analyzing the steering resistance torque, and then the proportional relationship between the power assist torque and the motor current is determined. Finally, the PID control algorithm is designed to set the control parameters automatically. Finally, the main program of the control system is set up, and the bus is used as the connecting medium to control the driving torque of the vehicle. The experimental results show that the system has good steering performance, and the test results of steering Angle, yaw velocity, lateral acceleration and offset path are better than those of the existing system, which is beneficial to the safe driving of the vehicle.

Keywords: Internet of Things · PID · Automotive electronic control · Power steering

1 Introduction

With the rapid development of the automotive industry, people have higher and higher requirements for vehicle performance. Among them, the performance that attracts the most attention is the smoothness and handling stability of the vehicle. The electronically controlled power steering system of a vehicle is a key component that affects the ride comfort and handling stability of the vehicle. Therefore, the research and development of the vehicle steering system has become the key for major manufacturers to improve the performance of their vehicles. During the steering of the vehicle, the power steering system assists the driver in steering the vehicle by providing steering power.

The steering system of a vehicle is very important for handling stability. The automobile steering system has gone through three development stages of pure mechanical steering system, hydraulic power steering system, and electronically controlled power steering system. The steering force of the mechanical steering system is all provided by people, and it is mainly composed of three parts: steering mechanism,

steering gear and steering transmission mechanism. The mechanical steering system has a simple structure and strong reliability, but it is quite laborious to use, and stability, accuracy, and safety cannot be guaranteed. The hydraulic power steering system adds a hydraulic device to the mechanical steering system. Under normal circumstances, most of the force required for car steering is provided by the hydraulic assist device, and the driver only provides a very small part of the torque as a signal [1]. Hydraulic steering system has the advantages of flexible operation, light weight, and can relieve tire impact. Since its inception, it has been widely used in automobiles. But the hydraulic power steering system cannot solve the coexistence of low-speed steering portability and high-speed steering stability. In addition, the hydraulic oil pump keeps working while the car is running, which increases fuel consumption, which restricts its own development. As a new generation of automotive steering systems, electronically controlled power steering systems are applied to various types of automobiles at a tremendous growth rate every year. In the early years, because of cost issues, the electronically controlled power steering system became synonymous with high-end cars. In recent years, electronic technology has developed rapidly and the prices of electronic components have been continuously reduced, making it possible to greatly reduce the cost of electronically controlled power steering systems and mass production. Electronically controlled power steering systems are also occupying more shares in automotive steering systems. Compared with traditional steering systems, electronically controlled power steering systems have many advantages, making them more and more popular. Its advantages are: it can provide the best assistance under various working conditions, which improves the fuel economy of the car; the system is directly assisted by the motor, which can also provide assistance when the engine is stalled or malfunctions; it has a compact structure and few parts. It is easy to install and assemble; it has good low-temperature working performance, and has higher reliability and safety; it can greatly reduce development costs and improve development efficiency. It only depends on changing the control strategy of the system to meet the needs of different models and different drivers.

In the process of vehicle steering, in order to improve the steering portability and steering stability of the vehicle, reasonable and effective control of the electronically controlled power steering system is the key to ensuring its good performance [2]. PID control controls the torque output of the booster motor by converting the current signal into the control voltage signal, so as to achieve the control effect of the electronically controlled power steering system, and improve the smoothness of the vehicle, the steering stability, and the ease of steering. Comprehensive performance is of great significance. Therefore, this article designs a PID based automotive electronically controlled power steering system under the Internet of Things environment to promote the industrial development of my country's automotive power steering system and enhance the international competitiveness of the automotive industry. The design idea of this system is as follows:

- (1) The combined power supply mode is used to form a switching step-down circuit by using the internal switching mode and the external circuit. Then the drive circuit is designed and the output end is flexibly configured through the control pins.

- (2) The steering resistance moment was analyzed and the vehicle system dynamics model was established. After determining the proportional relationship between the power torque and the motor current, the power steering control algorithm was designed based on PID, so as to automatically set the control parameters.

2 The Hardware Design of the Automotive Electronically Controlled Power Steering System Based on PID in the Internet of Things Environment

The hardware circuit of the automobile electronically controlled power steering system is the basis for the implementation of advanced engine control methods and control strategies. Therefore, research and development of a reliable and good-performance hardware circuit board is of great significance. The main modules of the hardware circuit are analyzed below.

2.1 Controller Selection and Circuit Design

In order to simplify the design of the hardware circuit board of the automotive electronically controlled power steering system and improve the operational reliability, a microcontroller with rich on-chip resources should be selected. On-chip resources include A/D converters, communication interfaces CAN, SPI, voltage converters, etc. Based on the principle of being able to meet design requirements and not pursuing extreme performance, this article selects Infineon's microcontroller SAK-TC1782F-320F180HL as the main control chip. TC1782 is an excellent high-performance microcontroller, used in complex embedded control systems, mainly used in engine and gearbox control. It has the characteristics of high cost performance, strong computing power, and fast real-time response. The highest frequency of TC1728 can reach 180 MHz, and the internal integration of 2.5M PFlash and 128K Dflash. TC1782 uses reduced instruction set computing (RISC) processor architecture, which achieves high computing bandwidth at a lower system cost. It integrates digital signal processing (DSP) operation and addressing mode. This mode provides powerful computing power and can effectively analyze various complex signals in the real world [3]. TC1728 has 2 independent ADC modules, a total of 32 analog signal input channels with a conversion accuracy of 10 bits, and a total of 86 digital general-purpose I/O ports. TC1782 also integrates TriCore CPU, multiple buses, bus arbitration, interrupt controller, peripheral control processor, DMA controller and multiple on-chip peripherals. Whether the TC1782 microcontroller can work normally depends on the quality of the minimum system circuit design. The minimum system circuit is composed of power supply, reset, oscillation, external expansion circuit, and program download and debugging. The designed external key-press hardware trigger reset circuit is shown in Fig. 1.

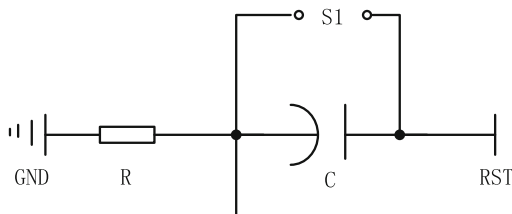


Fig. 1. Reset circuit design

TC1782 is divided into warm reset and cold reset. The warm reset includes watchdog timer (WDT) trigger reset, debug (OCDS) trigger reset, software reset (SW) and external power-on hardware automatic reset, etc.; cold reset includes the above Electrical reset trigger request (PORST); TC1782 is a high-level reset chip. Pull the reset pin /PORST level within 0.1 μ S, and the microcontroller can reset once. VCC is the microcontroller power supply 5V, RST is connected to the reset pin of the microcontroller, the capacitance is a 10UF electrolytic capacitor, and the resistance is a 10K ceramic resistor. This circuit resets once when the control system is powered on, and the system resets again when the button is pressed [4]. Therefore, the operating system is reset by closing and opening the button. The crystal oscillator frequency supported by TC1782 is between 8–40 Hz, and the crystal oscillator circuit diagram designed is shown in Fig. 2.

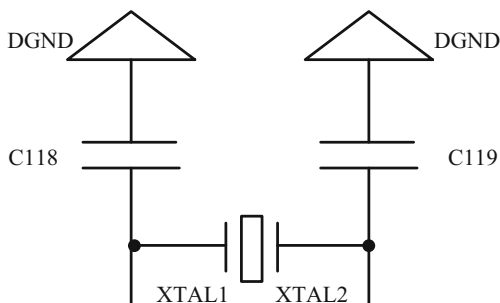


Fig. 2. Crystal oscillator circuit design

The parameters of each component in the circuit are designed according to the values recommended by the manufacturer. The capacitance is 33 pF, the crystal oscillator is 20 MHz, and the two ends of the crystal oscillator are respectively connected to the XTAL1 and XTAL2 pins of the microcontroller. The circuit is connected to the oscillator inside the single-chip microcomputer through the above two pins to provide a square wave of the clock signal for the single-chip microcomputer, and the circuit has no active components, so the designed circuit is called a passive internal clock oscillation circuit.

2.2 Power Module Design

The power supply of the controller is an important guarantee for the normal operation of the power steering system, so the design of the power supply should meet the following requirements: (1) When designing the power supply voltage of the MCU I/O port, the compatibility with the input level of the peripheral drive circuit should be taken into account; (2) The voltage of the ADC module must be accurate, and the voltage value must be greater than or equal to the voltage value of the input sensor signal; (3) the current load capacity of the power supply circuit should meet the requirements; (4) In order to make the circuit low power consumption, stable performance and good electromagnetic compatibility, according to the actual situation to choose the best power supply mode [5].

The various modules of the controller require different power supply voltages. The CPU core requires 1.3 V to reduce power consumption, the I/O port module requires 3.3 V or 5 V power supply, and the ADC module requires 5 V power supply. Therefore, the controller requires a total of 5 V, 3.3 V and 1.3 V power supply. TC1782 integrates two voltage regulators, 3.3 V and 1.3 V. 1.3 V includes linear step-down mode and switching step-down mode. The external power supply module uses TLE7368-3E recommended by Infineon. This chip can output 5 V, There are 3 voltages of 3.3 V and 1.3 V, so the power supply mode of TC1782 is very flexible. Through the flexible combination of internal and external power supply modules, this article adopts the combined power supply mode recommended by Infineon. The external power supply is 5 V and 3.3 V, and the internal switching mode of the 1.3 V regulator and the external circuit form a switching step-down circuit. Because the difference between the external 5 V power supply voltage and 1.3 V is too large, if 1.3 V uses the linear step-down mode, the energy consumption inside the microcontroller is too large, causing the microcontroller to heat up, so the above recommended mode is used to power the microcontroller. TLE7368 is a power chip specially produced by Infineon for the Powertrain system. The chip can provide 5 V, 3.3 V and 1.3 V power supply voltages and functional safety testing for 32-bit microcontrollers. TLE7368 first uses a pre-regulator to output a 5.5 V pre-regulated voltage, and then uses a linear regulator to convert the voltage to 5 V, 3.3 V, and 1.3 V. This can reduce power consumption and improve voltage accuracy, and the output voltage accuracy is 2%. Among them, the current load capacity of 5 V and 3.3 V is 800 Ma. Most of the chips listed above are in switch regulation mode. Compared with linear regulation mode power supply, switch regulation mode has many advantages such as low power consumption, high efficiency, small size, light weight, and wide voltage regulation range.

2.3 Drive Circuit Design

The design of the hardware drive circuit module of the power steering system is compatible with the requirements of the vacuum diaphragm and linear circulation valve on the drive circuit. The dual H-bridge drive chip L9960 based on STMicroelectronics is used as the drive chip of the drive circuit. L9960 is a dual H type driver chip specially launched by STMicroelectronics for automotive-grade motor drive, mainly

used for power steering control. L9960 mainly has the following features: flexible configuration of the output terminal through the control pin; battery voltage range from 4.5 V to 28 V; chip power supply voltage from 4.5 V to 5.5 V; input switching frequency up to 20 kHz; input logic level compatible with 3.3 V and 5 V; integrated chip power supply monitoring module; integrated short-circuit protection, over-temperature protection module; integrated SPI interface and self-diagnosis module. The drive circuit module circuit designed based on the L9960 drive chip is simple, uses fewer components, works stably, and has better performance. The driving circuit is shown in Fig. 3.

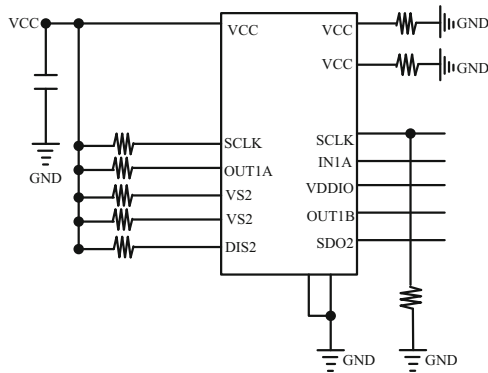


Fig. 3. Drive circuit design

When the actuator adopts the vacuum diaphragm type, a low-end output is used to control the current of the vacuum solenoid valve; when the linear valve is used as the actuator, an H bridge is used as the control of the solenoid coil. The working process of the vacuum diaphragm valve is: a valve stem and a spring are connected to both ends of the rubber membrane [6]. Under normal circumstances, the spring force makes the valve stem tightly against the valve seat, so that the valve is in a closed state. When the vacuum force on the rubber diaphragm in the direction of the vacuum port is greater than the spring force, the valve stem is pulled away from the valve seat, the EGR valve opens, and the exhaust gas enters the intake pipe from the exhaust pipe through the valve port. When the vacuum force on the rubber diaphragm in the direction of the vacuum port is less than the spring force, the rubber diaphragm drives the valve stem to fall back to the valve seat, and the valve port is closed. Therefore, the opening of the valve port is controlled by the degree of vacuum, and the degree of vacuum is controlled according to the actual working conditions of the engine, so it is also indirectly controlled by the vacuum solenoid valve. There is a solenoid coil group and an armature inside the linear valve. The electromagnetic coil is driven to generate electromagnetic force, so that the armature shaft pulls the cone valve up, the valve port opens, and the exhaust gas flows from the exhaust manifold into the intake manifold. The valve port position sensor is actually a linear potentiometer, and its range is between 1–4.5 V from closed to open. The optimal EGR rate is calculated according to

various parameters of the engine, combined with the position sensor feedback position signal, and the on-off of the solenoid current is controlled by outputting a PWM modulation signal to achieve linear and precise control purposes. Compared with the vacuum diaphragm valve, although the linear valve has a complicated structure and a higher cost, it has unique advantages in control accuracy and closed-loop control, so it is also widely used in many high-end cars. According to the control requirements of the power steering system, a microcontroller is selected and a reasonable control circuit is designed.

3 PID Based Automotive Electronic Control Power Steering System Software Design in the Internet of Things Environment

3.1 Establish Vehicle System Dynamics Model

The automobile electronically controlled power steering system is actually a complex system composed of many non-linear links. In order to ensure the correctness of the established model, it is necessary to simplify the secondary factors and uncertain conditions in the mathematical model. This chapter establishes a dynamic model for the power steering system. The force in the power steering system is mainly the steering force acting on the steering wheel by the driver, the assist torque of the assist motor, and the internal and external resistance torque of the entire steering system. The driving force of the driver mainly includes the steering force when steering the car and the holding force during turning. The resistance torque of the steering system mainly includes the internal resistance torque of the steering system and the external resistance torque generated by the tires. Among them, the internal resistance moment of the steering system includes the friction resistance moment of the steering system, the restoring moment of the steering system, the inertia moment of the steering system, etc.; the external resistance moment is the resistance moment generated by the tire and the ground around the kingpin [7]. In order to obtain accurate dynamic characteristics of system steering and manipulation, a mathematical model of the system must be built, that is, a mathematical expression of the dynamic characteristics of the system. The correct system mathematical model can also be used for the selection and calculation of system component parameters, guide the software and hardware development of the electronic control unit, and can also be used for subsequent research on the influence of control parameters on vehicle handling and stability, and for the construction of subsequent test benches. All have important guiding significance. According to the structure of the power steering system, the power steering system can be divided into four components: steering wheel and steering input shaft, steering output shaft, rack and motor. The assist torque of the electric motor acts on the steering output shaft. According to Newton's law, the established dynamic equation of steering system is:

$$w\alpha + e\beta = s + hj - kr \quad (1)$$

In formula (1), w represents the stiffness of the sensor torsion bar; α represents the angle between the steering wheel and the steering input shaft; e represents the damping coefficient of the steering shaft; β represents the angle between the steering wheel and the steering output shaft; s represents the detected torque; h represents the reduction ratio of the reducer; j represents the electromagnetic torque of the motor; k represents the equivalent force of the tire return torque on the rack; r represents the radius of the pinion. The torque sensor is based on the angle difference between the steering wheel angle and the lower steering output shaft as the measurement object, so it can be simplified as a torsion spring, so the calculation formula for the detected torque is:

$$s = w(\theta_1 - \theta_2) \quad (2)$$

In formula (2), θ_1 represents the steering shaft angle; θ_2 represents the steering pinion angle. In this way, the normalizing torque and the cornering angle of the front and rear wheels can be changed in time with the changes in the driving state of the vehicle, and the force is more in line with the actual situation. To get the steering wheel torque of a car, you must first know the tire's aligning torque, and the tyre's aligning torque is related to the tire slip angle. The tire slip angle is the car's center of mass slip angle, yaw rate, body roll angle, and A function of the front wheel angle [8]. Therefore, a complete vehicle model of motor sports must be established. The movement of the car can be described by the Cartesian coordinate system of OXYZ vehicle coordinate system. XOZ is in the symmetrical plane of the car. When the vehicle is at a standstill on a level road, the X axis is parallel to the ground and points forward, the Z axis points upward through the center of mass, and the Y axis points to the driver's left side. The origin O of the coordinate system coincides with the center of mass. The entire coordinate system conforms to the right-handed spiral rule. When the car is turning, the body roll will cause the vertical load of the inner and outer tires to change, which affects the lateral force and the torque of the tire. In this chapter, through the analysis of the steering resistance torque of the power steering system, the relationship expression between the steering wheel torque and the steering resistance torque is established, which lays the foundation for the research of the control strategy and the construction of the simulation model.

3.2 Set the Parameters of the Assist Characteristic Curve

The assist characteristic refers to the relationship between the steering wheel torque and the assist torque or the assist current. After the power steering system receives the steering wheel torque signal and the vehicle speed signal, it can determine the value of the assist current applied to the motor according to the assist characteristics. For a booster motor, the actual boost torque of the motor is controlled according to the delivered boost current. For the electric power steering system, the magnitude of the assist torque provided by it is proportional to the current of the motor, so the assist characteristic is represented by the relationship between the motor current, vehicle speed and steering wheel torque [9]. The ideal assist characteristics should be able to fully coordinate the steering ease of the vehicle and the perception of the road surface. Under the premise of satisfying the steering portability of the vehicle, the road feel does

not change much, so that the driver can judge the change of the vehicle driving condition. In order to make the driver handy in the steering process of the vehicle, the electric power steering system should try to meet the driver's original driving habits. The basic requirement that the assist characteristics should meet is the relationship between the steering wheel torque and the assist torque. Under normal circumstances, there are three main forms of the assist characteristic curve, linear type, polyline type and curved type. The linear power assist characteristic curve is the most intuitive, which can make the design of the control system easier and easier in the control process. However, because the output of the assist characteristic curve is linear, the driver feels uniform on the road surface. The curve-shaped power assist characteristic curve is more complicated, and a large amount of data is needed for support in the process of determining the curve, and it is not easy to adjust in the actual use process, so this method is not used in this article. The characteristic of the broken line assist characteristic curve lies between a straight line and a curved line. In summary, the design of the linear boost characteristic curve is simple and easy to control, so this paper selects the linear boost characteristic curve. In the broken-line assist characteristic curve, in the part of the assist change, the steering assist current has a piecewise linear relationship with the steering wheel torque, and its function expression is as follows:

$$C = \begin{cases} 0, & 0 \leq J < J_0 \\ a(J - J_0), & J_0 \leq J < J_1 \\ a_2(J - J_1) + a_1(J_1 - J_0), & J_1 \leq J < J_{\max} \\ C_{\max}, & J \geq J_{\max} \end{cases} \quad (3)$$

In formula (3), C represents the assist current of the electric motor; a, a_1, a_2 represents the gradient of the assist characteristic curve; J represents the torque input by the steering wheel; J_0 represents the input torque of the steering wheel when the power steering system starts assisting; J_1 represents the assist characteristic The steering wheel input torque when the curve gradient changes from a_1 to a_2 ; J_{\max} represents the steering wheel input torque when the power steering system can provide the maximum assist; C_{\max} represents the maximum operating current of the electric motor. According to the established assist characteristic curve, three basic characteristic parameters need to be determined, namely the input torque J_0 of the steering wheel when the system starts assisting, the gradient coefficient a of the assist characteristic curve and the steering wheel input rotation when the maximum assist is provided. When the vehicle is turning, the driver turns the steering wheel to make the vehicle make a steering movement. In this process, the force acting on the steering wheel should be within an appropriate range, neither too large nor too small. According to the sensitivity of human perception, when the steering torque input by the steering wheel is less than a specific value J_0 , then the assist motor does not provide steering assistance. This method is also helpful to reduce fuel consumption, so the value of J_0 is 1. The assist torque output by the assist motor has a maximum upper limit. When the steering wheel input torque reaches a certain value, the maximum torque is output when the control current reaches the maximum. At this time, the steering assist torque will not continue to increase, so that the motor can be Some protection, so the value of J_{\max} is 7. At different vehicle speeds, the value of the gradient coefficient a of the assist

characteristic curve is different, and the value decreases as the vehicle speed increases. This value indicates that the driver can fully feel the road surface information while ensuring the ease of steering while the vehicle is driving. The gradient coefficient of the assist characteristic curve set in this paper is shown in Table 1.

Table 1. Gradient coefficient table of boost characteristic curve

Speed	Gradient coefficient	Speed	Gradient coefficient
0	3.352	40	1.413
10	2.278	50	1.269
20	1.964	60	1.118
30	1.657	70	0.926

According to the selection of the parameter values of the above-mentioned assist characteristic curves, the design of the assist characteristic curve is completed, and a linear relationship between the assist current of the assist change part and the steering wheel torque is obtained.

3.3 Design of Power-Assisted Steering Control Algorithm Based on PID

The specific control process of the automobile electronically controlled power steering system is: the vehicle turns during driving, and the steering angle signal input by the steering wheel is converted into a torque signal. The power steering system receives the torque signal transmitted by the steering wheel and the vehicle speed signal and processes and analyzes it to output a current signal. This signal is the input signal of the PID controller by subtracting a current signal generated by the power-assisted motor during operation. The PID controller converts this signal into a control voltage signal through proportional-integral-derivative control to control the torque output of the booster motor, and then achieves the control effect of the electric power steering system through the actuator. In the process of using the PID controller to control, the proportional control link proportionally reflects the deviation signal of the control system. Once the deviation occurs, the controller immediately takes control to reduce the deviation, play the main control role, and make the system stable; The integral link is mainly used to eliminate the static error and improve the error-free degree of the system. The strength of the integral action depends on the integral coefficient. The smaller the integral coefficient, the weaker the integral action, and vice versa. The differential link reflects the change trend of the deviation signal, and can introduce a system into the system before the deviation signal becomes too large. Correct the signal early to speed up the action speed of the system, adjust quickly to eliminate the deviation and reduce the adjustment time. When the three control parameters are adjusted properly, the advantages of PID control can be fully utilized to obtain the ideal control effect. Its expression is:

$$Y = \lambda_1 + \frac{\lambda_2}{s} + \lambda_3 s \quad (4)$$

In formula (4), Y represents the transfer function; λ_1 represents the proportional coefficient; λ_2 represents the integral coefficient; λ_3 represents the differential coefficient; s represents the deviation. In order to complete PID control, three parameter values need to be set. Conventional parameter tuning methods are mainly proposed based on the first-order inertia model with delay. In practical applications, the tuning of the three parameters can be obtained by “trial and error” on the simulation model. The order of trial and error is carried out in accordance with the principle of first proportional, then integral, and then differential. However, in actual operation, the PID parameters are obtained by trial and error in a purely proportional manner. The trial and error process is highly repeatable, low in efficiency and has a lot to do with the experience of the technicians [10]. And in fact, there are many uncertain factors in the power steering system, such as random impact on the road surface and friction within the system. The parameters of the traditional PID control after debugging can only achieve good results in this state, and it is difficult to automatically adjust the parameters to obtain the optimal control parameters in the whole process, and the system control effect is often not ideal. Aiming at this problem, this paper uses sliding mode variable structure to improve the PID control algorithm [11]. The sliding mode deformation structure can force the system to move up and down with a small amplitude and high frequency along a prescribed state track under certain characteristics, which has nothing to do with the parameters and disturbances of the system, so the system can have good robustness. The approach speed of the exponential approaching law can be changed, and it has the advantages of not only accelerating approach time but also reducing chattering. Therefore, this article adopts the exponential approaching law control method, and its expression is:

$$l = -\eta \text{sgn}(v) - bv \quad (5)$$

In formula (5), l represents the output of the controller; η, b represents the reaching law coefficient; v represents the switching function, which is the error between the reference current and the actual current. In this case, the progressiveness of the sliding mode movement is stable and the dynamic quality is good [12]. Through the optimization of PID algorithm, the problem of PID control difficult to self-tuning control parameters can be better solved.

3.4 Set up the Control System Program

The design of the main program is the key and basic work for the establishment of system software. The initialization of the system is mainly the initialization of the port, the initialization of the area, and many other aspects. When the main program starts to operate, it will use multiple sensors of the system, such as acceleration and brake pedal sensors, clutch switch sensors, and gear switch input signals to enter the judgment mode and start the corresponding work. Then start each program mode and perform related operations. During the operation, the main program runs in the form of a loop,

and the change of the vehicle operation mode will cause the system to be interrupted. Use the controller to process the signals in the 0 and 5V voltage range from the acceleration and brake pedal position sensors, and use the A/D converter as the platform to realize the signal conversion. After the conversion operation is successfully completed, the corresponding signal will be obtained [13]. This result is mainly used to clarify and judge the driving condition of the car.

When the switch is closed, the system uses the engine as the main power of the vehicle and converts to the engine drive mode [14]. The difference between the engine speed and the starting speed should be defined at the beginning. If it is greater than the latter speed, then the system will not have a start command action. If the engine speed is less than the value of the starting speed, the system will judge the pressure of the accumulator at this moment. If the pressure of the accumulator is greater than the critical value, the hydraulic power system will be used to start the engine. If it is less than the critical value, the starter generator will be used to complete the start of the generator [15]. When the car's speed drops to zero, the engine will no longer continue to work at this moment, the car's gear is in a non-neutral state, the clutch angle is reduced, the accelerator pedal is gradually released, and the system will start the single hydraulic drive mode.

The main purpose of the electronic control unit is to complete the detection of the pressure of the accumulator. If the pressure signal is greater than the pre-required pressure threshold value, the detection will be initiated, and the detection of the displacement signal of the accelerator pedal will be performed at the same time. According to the test results, the variable displacement hydraulic pump and motor are calculated. When the speed is not zero, the gear is not neutral, the clutch is combined, the accelerator pedal is pressed, and the system will start the commonly used engine drive mode at this moment. With the bus as the connection medium, the power steering system will be connected to the engine, and the engine will perform the task of controlling the driving torque of the car at this moment. At this point, the design of each module of the software is completed. Combined with the hardware part, complete the design of the automotive electronically controlled power steering system.

4 Experimental Study

This paper designs a PID based automotive electronically controlled power steering system under the Internet of Things environment. In order to test the performance of the system, the following experiments are carried out to determine the effectiveness of the power steering system.

4.1 Experiment Preparation

According to the structure and performance parameters of the key components of the automobile studied in this paper, the parameters required in the simulation system are set, as shown in Table 2.

Table 2. Simulation parameter table

Serial number	Parameter name	Numerical value
1	Moment of inertia of steering wheel ($\text{kg}\cdot\text{m}^2$)	0.015
2	Steering column damping ($\text{N}\cdot\text{m}\cdot\text{s}/\text{r}$)	0.030
3	Equivalent moment of inertia of steering mechanism and front wheel ($\text{kg}\cdot\text{m}^2$)	0.015
4	Equivalent damping of steering mechanism and front wheel ($\text{N}\cdot\text{m}\cdot\text{s}/\text{r}$)	0.05
5	Steering gear ratio	25
6	Steering gear positive efficiency (%)	85
7	Torque sensor equivalent torsion bar stiffness ($\text{N}\cdot\text{m}/\text{deg}$)	2.5
8	Reducer transmission ratio	20
9	Reducer efficiency (%)	85
10	Moment of inertia of booster motor ($\text{kg}\cdot\text{m}^2$)	0.01
11	Assist motor damping ($\text{N}\cdot\text{m}\cdot\text{s}/\text{r}$)	0.03
12	Electromagnetic torque constant of booster motor ($\text{N}\cdot\text{m}/\text{A}$)	0.07
13	Assisted motor back electromotive force constant ($\text{V}\cdot\text{s}/\text{r}$)	0.015
14	Power-assisted motor resistance (Ω)	0.2
15	Booster motor inductance (H)	0.001

Under the condition of co-simulation, the steering angle step input is carried out, and the PID control parameters are adjusted. The determined PID control parameters are as follows: proportional coefficient 0.6, integral coefficient 0.0045 and differential coefficient 0.0001. After setting, the output current of the PID controller has a good consistency in tracking the target current. Under the above experimental platform and parameter settings, experiments are carried out to test the performance of the auto-motive electronically controlled power steering system.

4.2 Experimental Results and Analysis

In order to verify the application effect of this design system, it is compared with the existing automobile power steering system. This article mainly evaluates the steering performance of each system. The steering performance describes the various dynamic responses of the car under the driver's steering command, as well as the corresponding steering power, steering wheel force feedback, and steering feel. The steering performance can be divided into four evaluation areas: steering characteristics when driving in a straight line, steering characteristics when driving in a curve, steering wheel force characteristics, and response shock caused by steering. Through the analysis of steering performance, four parameters of steering wheel angle, yaw rate, lateral acceleration and offset path are selected as indicators of steering performance to evaluate the steering performance of each system. The experimental test results are shown in Tables 3, 4, 5 and 6.

Table 3. Test results of steering wheel angle (N·m)

Serial number	Design system	Existing system 1	Existing system 2
1	20.52	38.42	39.21
2	21.24	38.26	39.64
3	20.65	38.58	39.47
4	20.88	38.47	39.54
5	20.76	38.74	39.76
6	21.17	38.49	39.65
7	21.22	38.55	39.87
8	20.58	38.62	40.28
9	20.63	38.54	40.14
10	20.84	38.33	39.88

According to the steering wheel angle test results in Table 3, the average steering wheel angle of the design system in this paper is 20.85 N·m, and the average steering wheel angle of the existing design system is 38.50 N·m and 39.74 N·m, indicating that the system is designed in this paper during the steering process. The steering torque is smaller, and the power-assisted control effect is better and obvious.

Table 4. Test results of yaw rate (deg/s)

Serial number	Design system	Existing system 1	Existing system 2
1	6.88	8.26	9.64
2	6.56	8.37	9.88
3	6.65	8.55	9.85
4	6.62	8.42	9.77
5	6.84	8.34	9.65
6	6.91	8.62	9.56
7	6.75	8.58	9.88
8	6.87	8.42	9.64
9	6.54	8.53	9.71
10	6.88	8.68	9.62

According to the yaw rate test results in Table 4, the average yaw rate of the system designed in this paper is 6.75 °/s, and the average yaw rate of the existing design system is 8.48 °/s and 9.72 °/s. The yaw rate of the system designed in this paper is 8.48 °/s and 9.72 °/s. The angular velocity is less than that of the existing system, which shows that the system designed in this paper can improve the handling stability.

Table 5. Lateral acceleration test results (g)

Serial number	Design system	Existing system 1	Existing system 2
1	1.36	2.62	3.23
2	1.25	2.84	3.35
3	1.37	2.87	3.46
4	1.32	2.78	3.33
5	1.58	2.66	3.54
6	1.34	2.85	3.48
7	1.59	2.64	3.62
8	1.24	2.51	3.59
9	1.23	2.64	3.42
10	1.45	2.83	3.35

According to the results of the lateral acceleration test in Table 5, the average lateral acceleration of the system designed in this paper is 1.37 g, and the average lateral acceleration of the existing design system is 2.72 g and 3.44 g, indicating that the system designed in this paper has good power-assisted characteristics and is easy to steer. Sex is strengthened.

Table 6. Offset path test results (m)

Serial number	Design system	Existing system 1	Existing system 2
1	2.62	3.82	4.23
2	2.54	4.03	4.34
3	2.75	4.14	4.45
4	2.67	3.97	4.58
5	2.88	3.95	4.39
6	2.56	3.86	4.42
7	2.44	3.68	4.35
8	2.55	3.77	4.27
9	2.68	3.95	4.26
10	2.82	3.82	4.34

According to the test results of the offset path in Table 6, the average offset path of the designed system in this paper is 2.65 m, and the average offset path of the existing design system is 3.90 m and 4.36 m. The path offset of the designed system in this paper has a significant reduction. Small, indicating good obstacle avoidance ability during driving.

Based on the above experimental test results, the PID based automotive electronically controlled power steering system designed in this paper has good steering performance. The test results of the four parameters of steering wheel angle, yaw rate, lateral acceleration and offset path are better than the existing ones. The system can

improve the handling stability and obstacle avoidance ability. The power-assisted steering effect of the designed system is better, which is conducive to the safe driving of the car.

5 Conclusion

In this paper, the design of automotive electronic control type power steering system based on PID under the Internet of Things environment is carried out from the hardware and software aspects. In the design process, the combined power mode is firstly adopted, and the internal switching mode and the external circuit are used to form a switching step-down circuit. Then the drive circuit is designed, and the output end is flexibly configured through the control pin. Based on this, the steering resistance torque is analyzed and the vehicle system dynamics model is established. After determining the proportional relationship between the power torque and the motor current, the power steering control algorithm is designed based on PID, and the control parameters are automatically set. The experimental results show that the system has good steering performance and good power steering effect, which is beneficial to the safe driving of the vehicle.

However, the work in this paper is only a theoretical simulation study, it is a pity that the designed system has not been tested on the bench and the actual vehicle, the effectiveness of the model and the accuracy of the control need to be tested in practice. These need to be solved in the future research.

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