Research on Adjustable K and C Values of Analogous Active Suspension System with Automotive Chip Electronic Control Technology

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***Abstract*—This research integrates the electronic control unit of the analogous active suspension system, which includes the adjustment of adjustable air springs, adjustable hydraulic dampers, and a variety of sensors, and retains the CAN Bus node, which can communicate with other electronic control units . This system can adjust the elastic coefficient K value of the spring and the damping coefficient C value of the hydraulic damper simultaneously through electronic control according to the different road conditions or user preferences. It also integrates the height, pressure value and six-axis inertia. The measuring sensor can monitor the dynamic characteristics of the car body. The suspension system is regulated by the electronic control unit to improve the comfort or handling during riding.**

***Index Terms*—analogous active suspension, K vale, C value, electronics control unit, controller**

I. Introduction

At present, the types of suspension systems for vehicles on the market can be roughly divided into passive, semi-active [1], and active[2]. Passive suspension needs to rely on inherent mechanical characteristics to cope with the current road conditions, so if the vehicle is driving on bumpy roads, the shaking will be more obvious; active suspension system requires additional design of actuators, which can generate force by themselves. Coupled with sensor monitoring, control the spring and damper. Active suspension not only costs more, but also consumes more energy. Therefore, the analogous active suspension system is proposed in [3], which is characterized by no need to install additional actuators, but regulates air springs and hydraulic dampers for existing suspension structures. This kind of suspension system not only improves the shortcomings of passive suspension fixing rigidity, but also solves the problem of high energy consumption of active suspension system.

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This research mainly focuses on the integration of electronic control units like analogous active suspension systems. In addition to adjusting the elastic coefficient K value of the air spring and the damping coefficient C value of the hydraulic damper, this system also includes the monitoring of the vehicle height, the pressure value of the air spring and the sensor of the six-axis inertial motion. After the system receives the signal from the sensor, it uses the microprocessor to calculate and adjust the air spring and hydraulic damper; or the vehicle's image monitoring unit, with the LIDAR and lens, pre-scans the road conditions ahead, and uses CAN Bus transmits instructions to the microprocessor, and controls the air spring and hydraulic damper through the microprocessor.

II. System Structure

Fig. 1 shows the composition of the analogous active suspension system where in the system comprises a controller, an air spring, solenoid valves, compressors, pressure relief valves, an accumulator, a hydraulic damper, motors, motor drives, and sensors, etc. Related parts. As a analogous active suspension system, in addition to the selection of air springs and hydraulic dampers with variable characteristics, the indispensable is the controller used in the system. Of course, under the premise that the system is electronic, its control methods are all transmitted by digital signals. Therefore, the solenoid valve that regulates the spring coefficient K value, the damping coefficient C value motor, and the controller form a dynamic suspension system-like An important component of electronics.

Among them, the air compressor is a part that provides air in the air cylinder, which can pump external air into the air cylinder to provide the amount of air required by the air spring; the purpose of the pressure relief valve is to store the air in the air cylinder to the maximum value, The pressure relief valve will keep the channel closed to keep the internal gas from leaking. Therefore, in analogous active suspension system, the air intake and

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drain of the air spring are delivered in a high-pressure manner to shorten its response time; the motor is one of the parts that regulate the hydraulic damper, and its purpose is to replace the manual adjustment. In this way, the controller adjusts the motor's forward or reverses rotation and the number of turns to adjust the external screw of the shock absorber to change the size of the internal oil passage, thereby changing the damping coefficient C value.

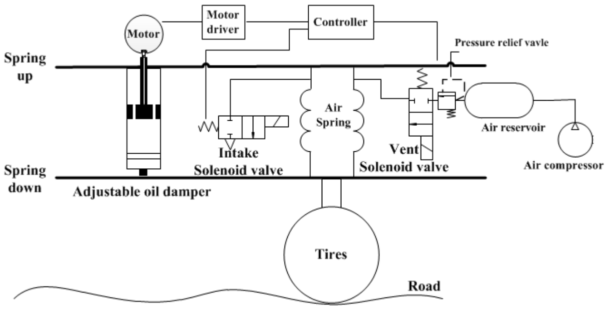

Figure 1. System schematic diagram[3]

Among them, in order to be able to automatically adjust the suspension system, the microprocessor is used as the core, and the solenoid valve, motor and sensor form the electronic control unit of the suspension system, as shown in Fig. 2. The following will introduce the various applications and components of the electronic control unit.

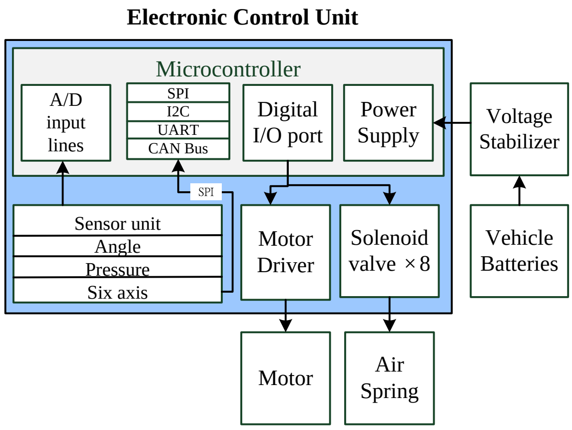

Figure 2. System electronics control unit

A. Sensor Unit

In this electronic control unit, there are three types of sensors: angle, pressure and six-axis gyroscope. Among them, the model of the angle sensor is RTY360LVNAX, as shown in Fig. 3. The sensing principle of this sensor is the Hall effect, which is a piezoelectric sensor with a measurement range of up to 360 degrees. Calculate the height of the vehicle chassis from the ground through the angle. After the vehicle is installed with this sensor, it can monitor whether the vehicle chassis is kept on the same horizontal plane. If the vehicle body rolls at an excessively large angle, the air spring can be used to reduce the degree of roll and slow down the shaking of the vehicle body.

Figure 3. Angle sensor

The model of the pressure sensor is 92CP8-11-ENV, as shown in Fig. 4. It is a piezoelectric sensor that can monitor the pressure value inside the air spring. When the pressure inside the spring is higher, the spring is harder; on the contrary, when the pressure inside the spring is smaller, the spring is softer. Therefore, in analogous active suspension system, the current status of the vehicle suspension can be known through the reading of the pressure sensor, and the air spring can be softened or hardened according to the road conditions in front of the vehicle in a timely manner to make the passengers feel comfortable.

Figure 4. Pressure sensor

The model of the six-axis gyroscope is ISM330DLC, as shown in Fig. 5. It can detect the three directions of three-dimensional space and Roll, Pitch, Yaw, a total of six directions of movement, and its data transmission type is SPI communication protocol. After the six-axis gyroscope is installed in analogous active suspension system, it can monitor multiple different moving directions of the vehicle, and make appropriate compensations through the air spring to reduce the deviation of the vehicle's center of gravity.

Figure 5. Six axis sensor

B. Motor Driver and Motor

The motor usually needs a driver to control it through a microprocessor. This system uses L298N and flywheel diodes to form three sets of half-bridge circuit drivers as shown in Fig. 6. Fig. 7 is the motor selected for this research, which is a three-phase stepping motor. Fig. 8 is a schematic diagram of the three-phase motor coils. U, V, and W, are three coils respectively. Using the six-step square wave excitation meter shown in Table I, the digital I/O port of the microprocessor follows the instructions in the table and Can drive motors.

When the motor rotates clockwise, the oil passage inside the damper will become smaller due to the orifice, which will increase the damping coefficient C value; on the contrary, when the motor rotates counterclockwise, the oil passage inside the damper will change due to the orifice. Larger, the damping coefficient C value becomes smaller.

Figure 6. Motor driver

Figure 7. 3 Phase motor

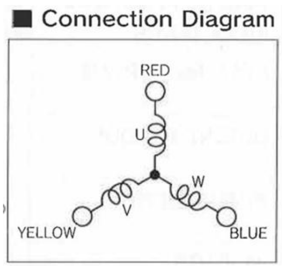

Figure 8. Motor internal diagram

TABLE I. MOTOR EXCITATION

	1	2	3	4	5	6
U Phase	+		—	—		+
V Phase	—	—		+	+	
W Phase		+	+		—	—

C. Solenoid Vavle

This system controls the opening and closing of the solenoid valve through the digital I/O port of the microprocessor to regulate the air spring intake or discharge. When 5 V is delivered to the solenoid valve, its circuit will be turned on; on the contrary, when the voltage is lower than 5 V, the circuit will remain closed. Among them, one solenoid valve is needed for air intake and exhaust air to control the conduction of air. When the intake solenoid valve is turned on, the air reservoir pours air into the air spring to increase the internal pressure of the spring and the spring becomes hard; on the contrary, when the bleed solenoid valve is turned on, the air spring vents the internal gas to the atmosphere, and the internal pressure of the spring As it becomes smaller, the spring becomes softer.

D. Microcontroller

There are many microprocessors on the market that can be used as the core of the vehicle's electronic control unit. In this study, a 32-bit car gauge microcontroller is used as the control core, the model is XMC4700-F144K2048AA, the oscillation frequency is up to 144MHz, and the working voltage is 3.3 V. This chip contains a lot of cells, and its internal structure is shown in Fig. 9. In this system, digital I/O, analog input lines, Timer, SPI, CAN bus and other related units are used.

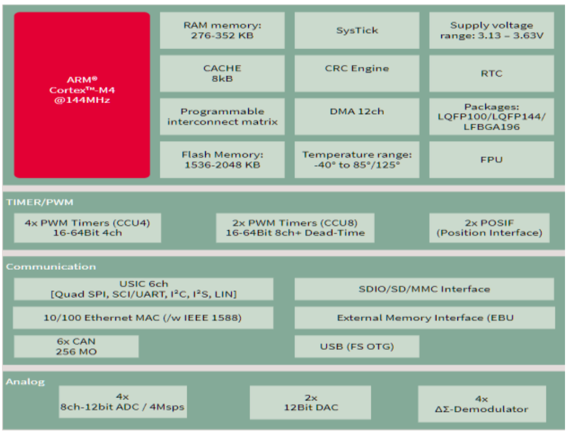

Figure 9 XMC4700 internal unit

E. Control Panel

After introducing the relevant components and applications used in the above electronic control unit, the following is the control board integrated and designed in this research. The control board integrates the relevant parts of the above electronic control unit, as shown in Fig. 10. In this controller, it can be divided into four major units: power circuit, solenoid valve control circuit, motor control circuit, and sensor related circuit, which will be described in detail below.

The power circuit is very important in the controller. If the power supply of the system is unstable, it will cause the system to fail, which will increase the danger brought by driving. Considering that the system will be installed on the vehicle in the future, the power conversion on the controller is all DC to DC, that is, 12 volts are used as the conversion to obtain 3.3 V and 5 V. This research uses ZLDO1117 series chips as power conversion. The chip integrates both step-down and voltage stabilization circuits, so it can save a lot of space.

The function of the solenoid valve control circuit is to control the air spring intake and discharge. This study uses MOSFET as its electronic switch, the model is P65NF06. The microprocessor controls whether the solenoid valve conducts the signal to the base of the MOSFET, and then conducts the gas. Since the microprocessor itself is a low-power control chip, the output voltage of the digital I/O port is 3.3 V. If the solenoid valve needs to be successfully pushed, it needs at least 5 V. Therefore, in the solenoid valve control circuit, The Schmitt trigger 7414 is used to increase the original output voltage to 5 V, while reducing external interference to successfully drive the solenoid valve to open or close.

The control circuit of the motor is as described above, and the driver is the control circuit of the motor. The microprocessor sends a signal to the motor driver L298N to drive the rotation of the motor, thereby changing the size of the oil passage inside the damper.

The sensor-related circuit is relatively simple, except for the conventional power line, ground and signal, as well as a filter circuit composed of 10 K resistors and 0.1uF. The six-axis gyroscope uses the SPI communication protocol for data transmission, so there is no filter circuit, but directly converts the read value inside the chip according to the communication specification and directly transmits it to the microprocessor[4]-[7].

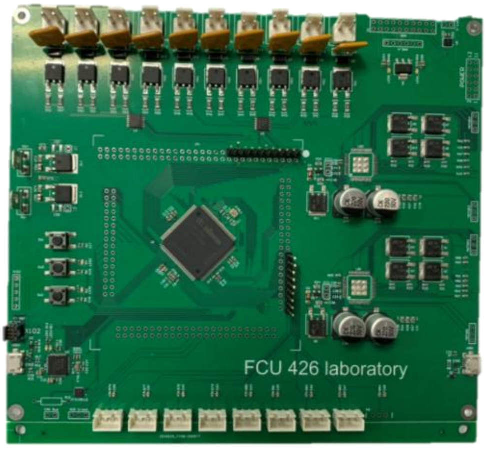

Figure 10 Control panel

III. Software Design

After the design of the controller is completed, the software is also one of the key technologies that constitute the system's stable operation. In this research, the program development interface is based on Eclipse and the software DAVE designed by microcontroller developers. The software is written using the open source C library newlib-nano as the program framework, which is characterized by strong portability, fast speed, and completes functions, so it is mostly used in various embedded systems.

Next is the description of the system program. In this controller, there is a main program and multiple sub-programs. Among them, the main program is responsible for the adjustment of the solenoid valve and the rotation of the motor. According to the received CAN Bus command or the sensor signal, the appropriate elastic coefficient K value and the damping coefficient C value are adjusted; the CAN Bus signal and sensor are read. The signal of the detector is achieved through the interrupt subroutine. In the CAN Bus subroutine, after initializing its settings and establishing the CAN protocol, it will wait for its command to be received, and finally return to the main program to control the solenoid valve and motor according to the received command; the sensor reads as Jump from the main program to the sub-program every 70 ns, read the voltage signal of the sensor and convert it at the same time to ensure that the system has the current sensor value. Fig. 11 shows the program flow of this system.

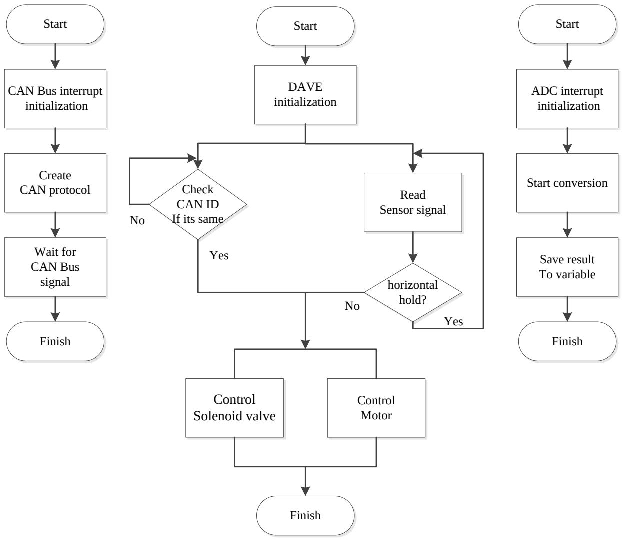

Figure 11. Program flow chart

Finally, there are related instructions for adjusting the elastic coefficient K value and the hydraulic damper C value. As described in the first half, the system has been designed for electronic control through a microprocessor, so whether it is adjusting the K value or C value, it is actuated by electronic signals.

In the part where the coefficient of elasticity K is adjusted, the solenoid valve for the air spring's intake and venting is used as a switch. When the microprocessor sends a high-potential signal, the solenoid valve is activated; on the contrary, when the microprocessor sends a low-potential, the solenoid valve is activated. The valve is closed. For example, if the spring is to be deflated, the high potential is sent to the deflation solenoid valve, and so on. The value of damping coefficient C is adjusted by the number of turns of the motor to achieve the adjustment of the internal oil passage. The motor can be divided into forward rotation and reverse rotation. When the microprocessor acts in accordance with the instructions from 1 to 6 in Table I, the motor rotates forward; on the contrary, when the microcontroller sends instructions from 6 to 1, the motor rotates in reverse. Therefore, the damping coefficient can become larger or smaller.

IV. Experimental Result and Discussion

Before the system is installed on the vehicle, in order to test the operating results of the system, the air spring test platform [1] is currently used to conduct related experiments and tests on the control board. After giving the corresponding power to the control board, the microprocessor can stably read the value given by the sensor, and can successfully control the air inlet solenoid valve or the bleed solenoid valve of the air spring and the forward or reverse rotation of the motor Or adjust the air spring and damper according to the received CAN Bus signal.

In the response time of the system, the running time of the air spring and the motor is calculated through the timer of the microprocessor. Figs. 12 and 13 show the time required for air spring and motor control. Among them, the average time required to adjust the air spring ±20 psi is 1.2~1.4 sec, and the running time of the code is about 0.17 seconds; the time required for the motor to rotate one revolution is about 1.8~2.0 sec, and the running time of the program is about 0.097 seconds.

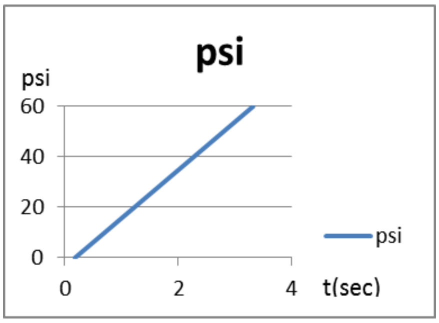

Figure 12. Air Spring response time

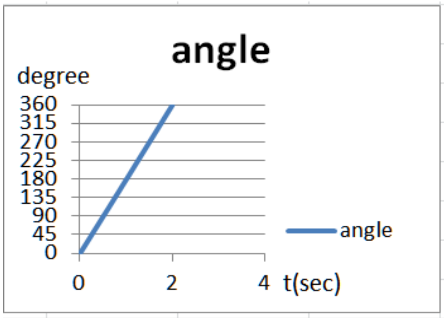

Figure 13. Motor response time

It can be known from the above experiment that the integrated control board of this research can control the air spring and the motor and achieve the adjustment of the spring coefficient K value and the damping coefficient C value, and the changes can be observed through the sensor. Therefore, if the analogous active suspension system and the electronic control unit developed by this research are installed on the vehicle, in addition to increasing the driving stability, the elastic coefficient K and the damping coefficient C can be adjusted in real time according to different road conditions; or When the center of gravity is deviated, it can be appropriately compensated by the air spring.

Among them, the response time is still slightly insufficient. If the vehicle speed is too fast, it may cause the system to respond poorly, cause discomfort to the passengers, and even cause safety on the road. The solution and improvement methods in addition to optimizing the program in the controller, or changing the hydraulic damper to an electromagnetic damper can effectively shorten the response time and provide a higher level of riding experience for the vehicle[8].

V. Conclusion and Future Works

With the advancement of semiconductor technology, the computing efficiency of chips is increasing year by year. With such a vigorous development, more and more electronic control units are mounted on vehicles. The regulation of the suspension system is often an important factor affecting the comfort of passengers. This research integrates the control of the K and C values of the suspension system, and monitors the movement of the vehicle body through sensors, so that when the vehicle is moving, it can be adjusted in real time through electronic control. Give passengers a comfortable ride experience.

At the same time, the review standards for automotive electronic circuits and the design of ordinary electronic circuits are more rigorous. The communication settings and circuit design installed in the vehicle must pass electromagnetic pulse tests to ensure that the vehicle's electronic control system is stable and not affected. When designing related electronic circuits, it is necessary to use components that have passed automotive specifications to meet the practicability of the system.

In the future, the system will be installed on the actual vehicle, and the relevant dynamic characteristics of the vehicle will be measured. Finally, the data read by the sensor will be used to optimize the control K value and C value to achieve the best Ride comfort and handling.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Professor S. S. Hung and Professor Y. C. Lin are responsible for the research guidance; Chi-Chun Hung and Kuo-Wei Lin are responsible for the research and data analysis, the paper is written by Chi-Chun Hung.; all authors had approved the final version.

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