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Study on an Innovative Hardware-based Controller for Driving an Automotive Exterior Rear-View Mirror Mechanism

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***Abstract*—The purpose of this paper is to design and develop a new controller based on a hardware circuit component that performs the task of driving and protecting the outside mirror base of an automobile to extend or fold inwards under safe conditions. By capturing the presence of the + 12V DC power supply and the polarity of the supply voltage, the system controller learns the intention of the automotive driver and immediately performs a rotation direction control of the driving DC motor (commonly known as the electric motor) inside the vehicle outside mirror base. During the controlling process, the system controller will dynamically detect the current flowing through the rear mirror body driving motor and performs over-current protection to effectively protect the driving motor and the controller circuit from over-current damage. In order to simplify the system controller circuit and reduce manufacturing costs as possible as, system DC motor controller circuit is designed by entirely using hardware circuit. This article is based on the general automotive rear-view mirror base motor drive and over-current protection requirements and then design based on a hardware circuit controller. The design ideas and the working principle of the all controller circuits are also introduced gradually in this article. In order to verify the working performance index of the vehicle exterior mirror body driving motor controller mentioned in this paper, a set of laboratory-scale driving motor controller prototype of the rearview mirror body will be set up in the laboratory. Under different experimental conditions, the completed system prototype experimental measurement and data collection will be carried out. Finally, through the collection of experimental data show that the design of the controller circuit functions and performance indicators can indeed meet the expected design goals of this paper.**

***Index Terms*—Controller, Automotive rearview mirror, Over-Current protection, DC motor.**

I. Introduction

In the past two decades, more and more fields of researchers began to study the different purposes of the vehicle rear-view mirror, the prototype products with different appearances and functions of the rearview mirrors have been developed by researchers and engineers [1]-[5]. Automotive rear-view mirror quality and function, in fact, it mainly provides drivers with information on people and things that are on the sides, backs and pavement of the car in terms of driving directions. Therefore, it is closely related to the driving safety of car drivers. Better exterior automotive rearview mirrors usually provide automobile drivers a wider field of vision and longer visual distances, reducing the chances of automotive drivers in traffic accidents. As the increasing development in global automotive electronics, people are more and more understanding of the theory about the best structure and appearance of the automobile rear-view mirror, Therefore, lots of designing cases concerned about the performance and appearance of the automotive rear-view mirror that have been improved and updated by many domestic and overseas experts, scholars and enterprise engineers [6]-[9].

When the car into smaller areas, such as building hall, parking, car rear-view mirror body location is the body where the widest part, in order to prevent the car body may lead to the result of being scratched, the timely reduction of body lateral occupy the space is necessary. In order to ensure that the exterior mirror mechanism is not damaged and the possibility of damage is minimized, it is necessary to fold the exterior mirror body mechanism in time. The traditional method of folding the exterior mirror is that it is impossible and dangerous for a driver to get out of the window by hand or directly to the outside of the automobile to fold the mirror directly. In order to thoroughly scrub the mirror of the automotive rear-view mirror, the automobile body often need to turn the mirror body outwards. With the development of electronic technology, automobile drivers on the functional requirements of auto parts are relatively more and more, so in the automotive rear-view mirror inward or outward folding action gradually changed the use of electric folding design , The driver can easily adjust the folding action of the rearview mirror on both sides of the automobile as long as the driver is in the automobile and solve the inconvenience and danger that many traditional rearview mirrors face in the folding operation.

II. The Controller Structure of Automotive Exterior Rear-View Mirror Base

The end position of automotive exterior rear-view mirror body is usually the maximum lateral width of the automobile. When the automobile parked or through the different locations, it always is a necessary action for utomobile's driver to stretch or fold the exterior rear-view mirror body. Fig. 1 is based on the general automotive vehicle exterior mirror base action needs, and designed contains over-current protection and DC motor drive controller circuit board. The controller circuit board includes a plurality of circuit blocks with different sub-functions. The functions of each sub-circuit of the controller, the design concept, and the operation principle will be respectively introduced as follows [10],[12],[13] :

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2.1 Voltage Polarity Converter

The internal computer of the vehicle not only changes the polarity of the DC voltage applied to the exterior mirror base controller to inform the controller that the current driver's desire to operate the mechanism is to fold or extend the motion. On the one hand, the functions of the functional block of the circuit are to provide the direct current motor in the body of the body as the rotating working power by the electric energy of the DC voltage input part input by the automobile body; in addition, the added voltage is further subjected to full wave rectification Circuit, and the output does not change with the voltage polarity of the vehicle body plus the DC voltage change, as the base controller circuit power supply.

2.2 Over-Current Detection Circuit

Until the DC motor because the body structure of the car rearview mirror was "blocked" and cannot continue to rotate, and eventually lead to the controller circuit over-current and stop the action in time to stop the supply of electricity to the controller circuit to stop the DC motor, or DC The motor will eventually be overheated and burned. In order to reduce the manufacturing cost, this paper designs to use a fixed resistor with low resistance in series with the DC motor to perform the task of dynamically detecting the current flowing through the DC motor.

The current sensing resistor is connected in series with the DC motor. The DC-motor current increase and reduce part of the power supply input voltage, so the actual addition of the DC motor at both ends of the potential difference to reduce and make it lower speed. When the over-current sensing resistor detects the over-current condition of the DC motor, an over-current signal "OC" with a high voltage logic level is generated immediately. In this paper, the over-current signal is used to reset the over-current signal On the other hand, this over-current signal is also designed to cut off the power supply and order the DC motor to stop rotating immediately to achieve over-current protection.

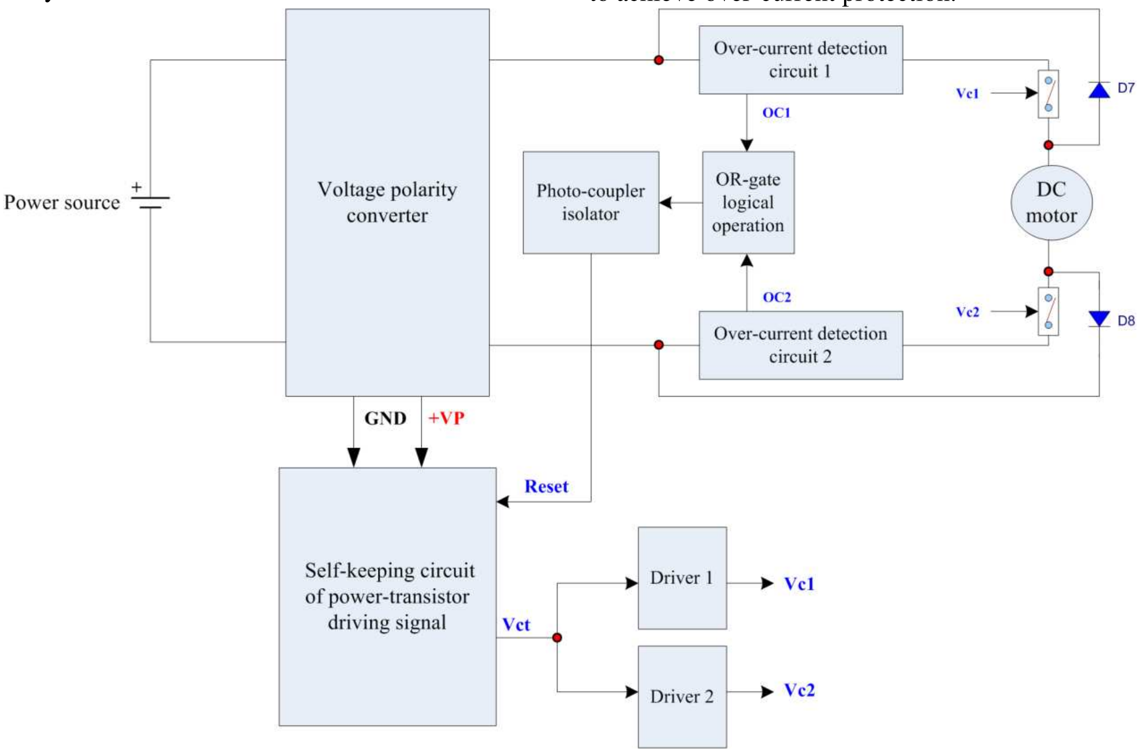


Figure 1. The functional block of the DC-motor controller circuit inside automotive exterior rear-view mirror base.

2.3 OR-gate Logical Operation Unit

The polarity of the voltage applied to the DC motor controller circuit in response to the body of the vehicle must be changed depending on whether the actual base of the mirror is to be folded inwards or outwards. To this end, the controller circuit is designed for the same DC motor with two sets of symmetrical Current sensing unit and drive circuit. Unexpectedly, the DC motor over-current protection circuit in the controller circuit would over-current the DC motor at that applied voltage polarity, so a circuit with "OR" gate logic operation was designed in the controller circuit. In this way, when any one of the current sensing units detects that an over-current event occurs in the DC motor, the over-current signal OC1 or OC2 transits to the high voltage logic level. After the "OR gate" logic operation, a logic high level over-current signal "OC" will be generated at the output of the OR gate logic in a general sense or independent of the polarity of the controller circuit positive supply voltage.

2.4 Photo-Coupler Isolator

DC motor over-current sensing element output voltage across the end of the "OR" gate logic circuit after the operation, the actual potential difference level has been significantly reduced. Since it is very likely that a potential difference is lower than the critical operating voltage, the over-current protection circuit in the controller circuit cannot be directly and timely reset. When the current in the primary side of the photo-coupler isolation circuit flows due to an applied voltage, its secondary side outputs the highest voltage in the over-current protection circuit, which is sufficient to reset the voltage in the controller circuit latch circuit.

2.5 Latch Circuit

This latch circuit block is designed to deal with the moment when the body is applied to the DC power supply of the controller circuit, so that the latch circuit automatically generates a pulse signal having a high voltage level. The latch circuit namely uses the voltage pulse signal to drive two small power transistors generate signal self-locking function. Meanwhile, two main power transistors cascaded with DC motor are enabled. When the DC motor is rotated to touch any one of two limited positions, there is over-current event occurs at this time.

2.6 Bypass Diode

With the addition of the vehicle body to the exterior rearview mirror DC motor voltage polarity of the DC motor rotation direction should also be changed, and the DC motor connected in series with the main power crystal control switch in theory at any one time can only one be turn on. The power transistors that is not situated in the conducting state, its bypass diode is then be turn on flows the DC motor current. Thus, effectively reducing the voltage drop across the non-conducting main power transistor, the DC-motor speed cannot be affected by the voltage drop of the power-off transistor.

III CONTROLLER CIRCUIT DESIGN OF DC MOTOR

3.1 Rectifier Circuit Design

However, considering the DC motor controller circuit should be as simple as possible to reduce costs and reduce circuit size. Regardless of the polarity of the voltage applied to the DC motor controller circuit by the automotive body, the operating power supply voltage value of the DC motor controller circuit must be unique and the polarity should be fixed. Fig. 2 shows that the body of the vehicle provided to the controller circuit is a +12 V DC voltage with a variable polarity. After this polarity variable voltage is processed by the bridge rectifier circuit designed in this article, the DC voltage at the output terminal + VP and ground. The output voltage value and its polarity are all fixed.

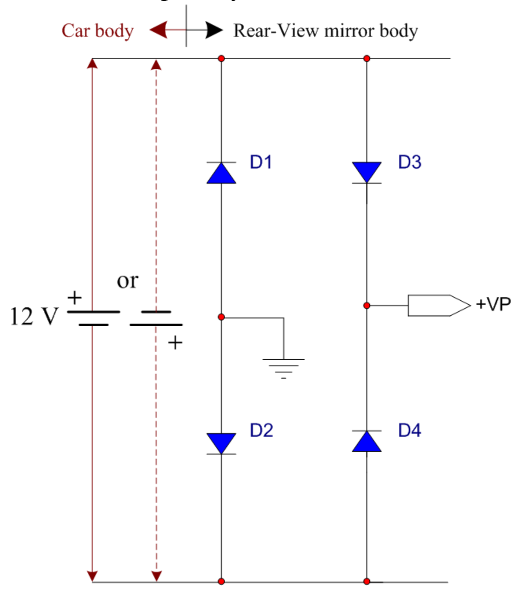


Figure 2. The DC power source of the controller circuit.

3.2 Over-Current Circuit

Taken the manufacturing cost into consideration, a constant resistor only has very low resistance is series with the measured DC motor and served as its current sensor. Therefore, there have the same current value flows through them. As mentioned earlier, with the actual needs of the rear-view mirror of the automobile, the operating voltage polarity of the DC motor is able to be changed. As shown in Fig. 3, over-current protection circuit in the event of over-current conditions, across one of the over-current sensing resistor (Rsc1 or Rsc2) will have a larger than the normal forward voltage drop. This forward voltage is typically designed to be greater than the V_{EB} threshold required. This forward voltage is used to turn on the transistor Q1 or Q2 and cause to enter into saturation state. The collector output voltage of Q1 or Q2 is approximately equal to the supply voltage + VP. The voltage of the V_{EB} of the transistor Q1 or Q2 is the product of the current sensing resistor and the current flows through the DC motor of exterior mirror mechanism. It can be expressed as follows:

$$V_{EB(Q_1)} = R_{SC} * I_L \quad (1)$$

where,

R_{SC} : the resistance across the DC-motor current sensor;

I_L : the current that flows through the measured DC motor.

From the Equ. (1), the voltage V_{EB} existed in transistor Q1 or Q2 is affected by the resistance value of the current sensor and the DC motor current. At the same DC-motor current, the over-current protection value is varied according to the resistance of the current sensor. Moreover, the maximum allowable safe operating current of DC motor inside of automotive exterior rear-mirror. The main purpose of this design is hoped to use a power transistor with less rated working current. Alternative control strategy is to select a power transistor with lower rated working current and a resistor with larger resistance value is needed to be served as current sensor.

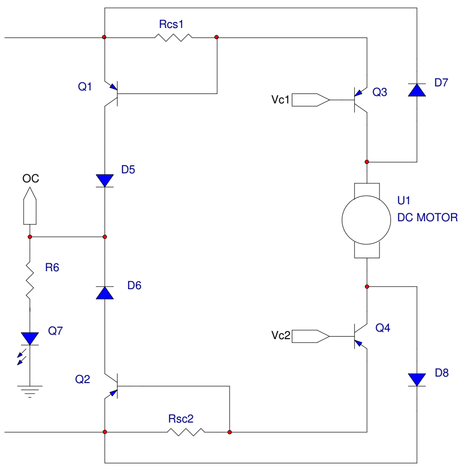


Figure 3. DC-Motor over-current protection circuit in controller circuit

As shown in Equ. (1), the same V_{EB} or protective effect can be obtained too. However, in practice, the choice of a relatively small capacity DC motor can generate enough torque to drive the mirror base mechanism to the desired extreme position, and with a higher current sense resistor, the DC motor of the starting current may cause over-current protection circuit action, the DC motor cannot start.

3.3 Main Power Transistor and Bypass Diode

The resistance at both ends of the current sensing resistor cannot be too large, otherwise the voltage across the DC motor will be reduced, the DC motor speed will decrease, and thus the power loss of the current sensing resistor will increase. The controller circuit caused by over-current protection circuit begins action. According to the requirements of a circuit operation, the simplest design method is to use two transistors together to form Darlington circuit or a single Darlington circuit, of course, the consequence of this is the circuit of the main power crystal purchase costs will therefore be increased. In addition to the maximum rated operating current of the main power transistor, it is necessary to ensure that the DC motor can operate continuously under safe conditions. The on-current value of the main power transistor is controlled by the base current value. In other words, we can achieve the goal of controlling the value of the allowable current flowing through the DC motor by adjusting the base resistance of the main power transistor.

3.4 Set Function in Latch Circuit

When the external DC power source is instantaneously applied to the controller circuit, there is a high logical level signal is generated in the base of power transistor Q6. Making use of this signal pulse, the power transistor, Q5, will be turn on. Circuit node in the Fig. 4, Vct, leads to generate a logical high level signal. Therefore, the transistors, Q8 and Q9, are turned on too. Circuit nodes, Vc1 and Vc2, are then output logical low levels at the same time. Any one power transistors will be turned on. The driven DC motor in automotive rear-mirror body begins rotating.

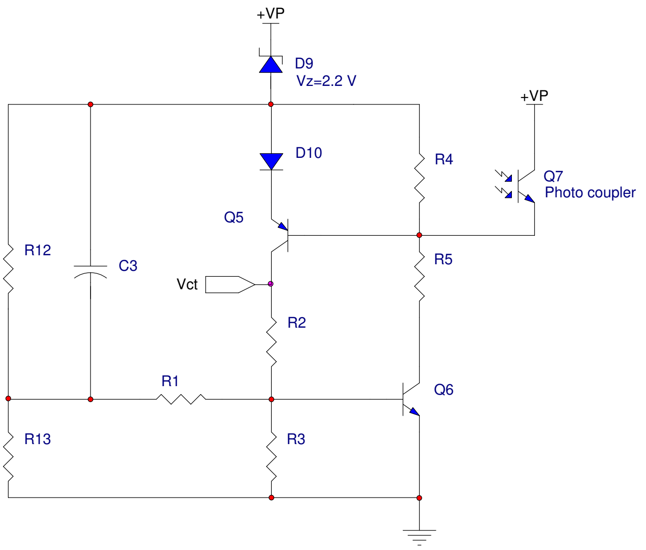
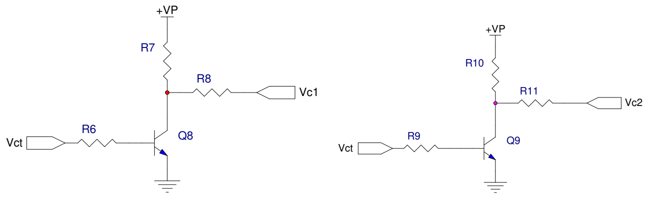


Figure 4. The circuit structure of Set function in the latch circuit.

Fig. 4 shows that latch circuit is initiated by the differential circuit which is made by the capacitor C3 and resistor R6. When the power source of the latch circuit, represented as +VP, is applied to latch circuit, the voltage across the capacitor C3 is shorted due to the instantaneous effect. One positive pulse with sustaining short time is generated. The transistor Q6 is namely triggered to turn on since this positive pulse. In case of transistor is turn on, there is a voltage across the resistor R4 will be generated since the collector current of Q6 flows through it. The logical level of node Vct becomes is high. This voltage is then divided into two parts by using resistors R2 and R3. The total time from the transistor is triggered to the voltage drop across the resistor R3 occurred. Transistors Q5 and Q6 are kept on working state. Although the transistor, Q6, is turn off since the short-time positive pulse disappeared. Finally, the transistors Q5 and Q6 are always kept on working and lead to the node voltage, Vct, is sustained on logical high level.

3.5 Driving Circuit of the Main Power Transistor

As shown in Fig. 3, if the automotive exterior rear-mirror is applied to different voltage polarity, transistor Q3 or Q4 will be turn on and begin working and controls the rotation direction of DC motor. Transistors Q3 and Q4 are PNP-type. If they are hoped to be triggered on, the voltage value between the emitter and base should be larger than 0.7 V. As mentioned above, the output signal, Vct, will be transmitted through two transistors Q8 and Q9 and became two driving signals respectively used to drive the main power transistors Q3 and Q4. If the output signal of latch signal, Vct, is logical high level, as shown in Fig. 5, these two signals will be used to drive the transistors Q8 and Q9 to work in the saturation state.



(a) (b)

Figure 5. Driving circuits of power transistors (a) Q3 (b) Q4

3.6 Reset Function in Latch Circuit

This article uses the voltage drop across the current sense resistor as the emitter-base voltage of transistors Q1 and Q2 so that the voltage drop across the current sense resistor will control whether transistors Q1 and Q2 conduct. When the DC motor operating current is too large, the sensing resistor Rsc1 and Rsc2 across the voltage drop greater than Q1 or Q2 emitter-base voltage, resulting in the transistor Q1 or Q2 conduction. When the transistor Q1 or Q2 is turned on, the voltage at its collector node is its emitter voltage minus the emitter-collector voltage drop in the saturation region, which is idealized to be zero, so the Q1 or Q2 collector terminal. The node voltage is almost equal to the power supply voltage. Because the body must be supplied with different polarity power supply voltage to the DC motor controller circuit, if the over-current signal must be unique, so as shown in Fig. 3, due to Q1 or Q2 conduction in its collector output "over-current" signal OC1 or OC2, using two diodes D5 and D6 and resistor R6 form a simple "OR" gate logic operation circuit.

The two over-current signals after the OR logic operation are connected to the primary side of the PC817 photo-coupler regardless of the polarity of the voltage applied to the controller circuit by the vehicle body. Once the operating current of the DC motor exceeds the rated operating current, the photo-coupler operates immediately and its secondary phototransistor begins to conduct and enters saturation, at its emitter terminal voltage nearly equal to the supply voltage, which is directly coupled to the self-holding circuit shown in Fig4 reset input or base of transistor Q5. When this voltage is greater than the emitter voltage of Q5, transistor Q5 enters the cut-off region.

IV EXPERIMENTS AND DISCUSSIONS

In order to verify the effectiveness and its working performance of the DC-motor controller circuit for driving the automotive exterior rear-view mirror, one laboratory-scale controller experimental prototype will be made in the laboratory according to the designing idea above-mentioned methods, it is shown in Fig. 6. Configure the controller circuit as planned in Fig. 1, one by one to complete the details of the circuit design and performance testing of sub-function blocks in the controller circuit.

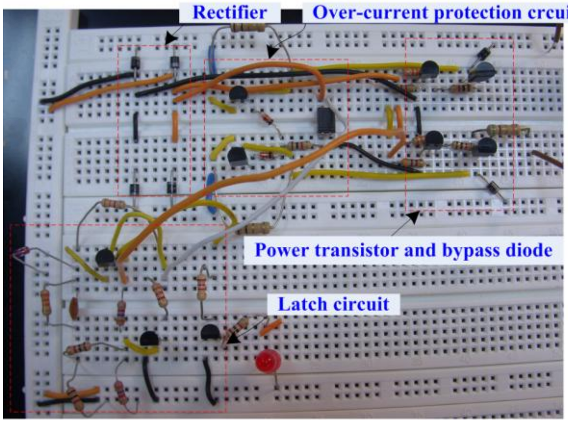


Figure 6. The physical prototype photo of the completed DC-motor controller.

4.1 Functional Verification of Over-Current Circuit Block

If the two current sensing units Rsc1 and Rsc2 in the over-current protection circuit of the DC motor controller circuit in the outside mirror body of the vehicle are both of $1\,\Omega$ resistor, DC motor is temporarily replaced by a fixed $5.1\,\Omega$ resistor to facilitate control or set the load current size. The main power transistor of the controller circuit is a PNP transistor. The base of the main power transistor is connected in series with a $2K\,\Omega$ resistor as a current-limiting resistor. When the controller circuit is supplied with +12 V DC voltage source and in the absence of load, the latch circuit will start normally.

In case of a $5.1\,\Omega$ is served as load resistance now, the load current sensing resistor Rsc causes the over-current protection circuit in the controller circuit to operate due to the flow of the reference current exceeding the set value. Fig. 7 shows the current waveform that flows through the current sensing resistor Rsc. The resistance value of the current resistor, Rsc, is $1\,\Omega$. Namely, the voltage drop across the resistor, Rsc, is equal to the current value flows through DC motor at the moment. In addition, Figure 8 also clearly shows that the moment change when the automobile adds to the controller circuit +12V DC power supply, the latch circuit actually begins working.

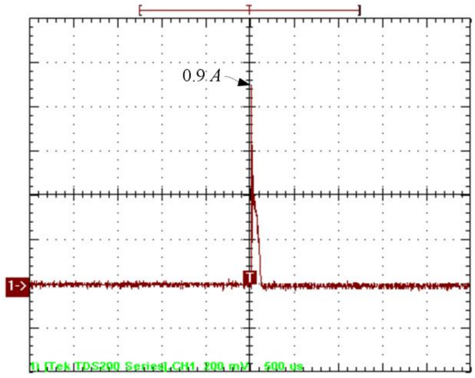


Figure 7. The shown waveform is load current when a fixed resistor, 5.1 ohm is served as load temporarily.

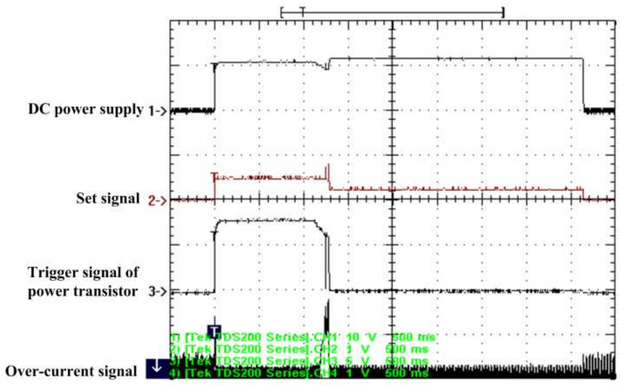
When the load is changed into another fixed resistor, $5.1\,\Omega$, the main circuit of the controller circuit happen over-current event and a signal is created and served as the reset signal of the latch circuit. Since there is a fixed resistor, 2K ohm, is in series with the base of power transistor. The base current is limited lower than $5.65\,mA$. Because the DC amplifier gain of the selected power transistor, h_{fe}, is around 150, therefore, the maximum collector current is also limited under about $847.5\,mA$. If the resistance of the selected over-current sensing resistor , Rsc, is equal to 1 ohm, the maximum load current or the current flows through the over-current sensing resistor is about $0.9\,A$. A voltage drop across Rsc is generated due to this load current.

Apparently, this voltage value has larger than the emitter-base voltage, V_{EB}, of the transistor Q1 or Q2. Any one of transistors Q1 or Q2 begins to conduct. The over-current function included in the controller circuit is then enabled to work. If the base current of power transistors is not limited, namely, the collector to emitter is similar to short circuit. The load, 5.1 ohm, is seemed to be connected to the DC power source, +12V. The maximum load current is limited to around $2.35\,A$. The actual waveform of the oscilloscope shown in Fig. 7 shows that the 5.1-ohm, the current waveform flowing through the load shows that the current flowing through the load's 5.1-ohm resistor does not go beyond the theoretical calculations value, $2A$. This means that the emitter or collector current of the main power transistor is controlled by the value of the base current. The base resistance of the main power transistor in series is 2K ohm resistance; the maximum collector current that can be generated by the main power transistor should be around approximately $847.5\,mA$. Now if the main circuit in the controller number 2SA684 transistor as the main power transistor can be used to meet the controller circuit of the main circuit pre-control DC motor operation or not, main power transistor operating point is still rated DC-motor operating current range.

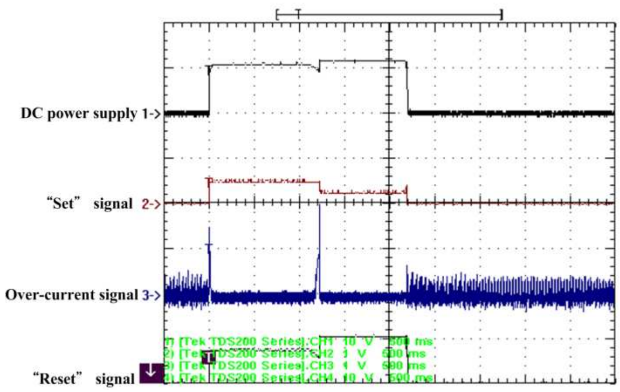
4.2 Important Node Voltage Waveform Measurement in the Controller Circuit

Fig. 8 (a) of the CH1 represents the power supply voltage waveform of the DC voltage applied to the controller circuit; CH2 indicates that the controller circuit generates a set signal or an excitation signal of the main power transistor after the external DC power supply is applied to the controller circuit; CH3 is the signal of the setting signal of CH2 after passing through the inverter composed of a primary transistor. The voltage level of the signal has been obviously amplified. This signal is used to activate the main power transistor to start conducting. CH4 is the output signal of the controller circuit over-current protection circuit.

Through the measurement of this signal can be observed when the automotive rear-view mirror base reaches the required position. The controller can automatically turn the main circuit off due to the main circuit over-current phenomenon continues to conduct. When a DC voltage is applied to the controller circuit, a setting signal is generated from the holding circuit, as shown in CH2 of Fig. 8(a). At the same time, set the signal and then driven by an inverter after the main power transistor is turned on, the signal shown in Fig. 8 (a) of the CH3. When the current flowing through the DC motor is around 1 A, the over-current protection circuit in the controller circuit will act immediately, as CH4 in Fig. 8 (a) or CH3 in Fig. 8 (b). The "OR gate" logic circuit outputs a high voltage level. The controller circuit uses this voltage level signal to reset the latch circuit through the optical coupling isolation circuit, and instructs the controller circuit state to return to the initial state.



(a)



(b)

Figure 10. Voltage Measurement Waveform for Critical Node of Controller Circuit

V Conclusion

The exterior side mirror of an automobile is one of the most important automotive components. It is one of the most important automotive components involves with the driving safety of most automotive drivers. The general location of the longest lateral vehicle components is the automobile exterior mirrors on both sides. In fact, automobiles sometimes have to temporarily immobilize the outside mirrors because they travel through some special location, the maximum width of the automotive route is less than the maximum width of the automobile, or to minimize the parking space required by the automobile The base folds up to allow the car to pass smoothly without damage. In the normal driving or without the above-mentioned special terrain and environmental space constraints, and then the car outside the rearview mirror fixed base stretch out to expand the driver's field of vision, minimize visual blindfold driver and blind spot and reduce car driving occurred dangerous possibilities. In this paper, the controller circuit of the automotive exterior rear-view mirror fixed base for folding and extension can be recognized the driver’s control intension based on the supplied voltage polarity from the DC power supply. When the exterior rear-view mirror base begins to rotate and reaches wanted position, the automotive exterior rear-view mirror base will timely stop rotating again. Not only meet the general basic functional requirements of the automotive exterior mirror fixed base, but also has simple structure and inexpensive feature.

Acknowledgment

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References

[1] Y. A. He and W. B. Zhang, “Modern Analysis and Prospect of the Rear-view Mirrors,” *Hai Xia Ke Xue,* Vol. 10, 2010, pp.147-149.

[2] T. Wada, M. Yoshida, S. Doi, and S. Tsutsumi, “ Characterization of Hurried Driving Based on Collision Risk and Attentional Allocation,” *13th Int. IEEE Conf. on Intelligent Transportation Systems*, 2010, pp. 623 – 628.

[3] K. C. Hu, F. Y. Lin, C. C. Chien, T. S. Tsai, C. H. Hsia, and J. S. Chiang, “Panoramic Image Stitching System for Automotive Applications,” *IEEE Int. Conf. on Consumer Electronics - Taiwan (ICCE-TW)*, 2014, pp. 203 – 204.

[4] S. Pardhy, C.Shankwitz, and M. Donath, “A Virtual Mirror for Assisting Drivers,” *Proc. of the IEEE Intelligent Vehicles Symposium*, 2000, pp. 255 – 260.

[5] M. B. van Leeuwen and F. C. A. Groen, “Motion Estimation in Image Sequences for Traffic Applications,” *Proc. of the 17th IEEE Conf. on Instrumentation and Measurement Technology*, Vol. 1, 2000, pp. 354 - 359.

[6] K. T. Song, C. H. Chen, and C. H. Huang, “Design and Experimental Study of an Ultrasonic Sensor System for Lateral Collision Avoidance at Low Speeds,” *IEEE Intelligent Vehicles Symposium*, 2004, pp. 647 – 652.

[7] R. L. Zheng, J. F. Qian, and J. Yong, “The Control System of Electric Memorial Back Mirror in Automobile,”*Automobile Technology*, Vol. 2, 2005, pp. 23-26.

[8] J. Morrell and K. Wasilewski, “Design and Evaluation of a Vibrotactile Seat to Improve Spatial Awareness While Driving,” *IEEE Haptics Symp.*, 2010, pp. 281 – 288.

[9] J. Zheng and X. Chen, “The Research of Vehicles' Rear-View Mirror Contours' Visual Pattern Based on Machine Vision,” *Remote Sensing, Environment and Transportation Engineering (RSETE), Int. Conf. on Remote Sensing, Environment and Transportation Engineering (RSETE),* 2011, pp. 5461–5464.

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