Design for Sensor-less Anti-pinch System for Automotive Electric Power Window

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Abstract

In order to effectively reduce the hidden trouble of electric window on automobile, many cars now use the electric windows anti-pinch systems. It adds anti-pinch circuit based on the window control module .PIC18F258 microcontroller samples and process the current of electric window motor .The method of combining current amplitude and current integral method is used to determine whether the window encounter obstacles, to achieve anti-pinch function. Through several experiments, it shows that the sensor-less anti-pinch system has good effects.

Keywords: *Anti-pinch; CAN Bus; PIC18F258; Without Sensor; Automotive Electric Window*

INTRODUCTION

More and more electronic equipments are applied in modern cars, improving the car's comfort, but also propose new requirements on the safety of the car, such as power windows on cars. The power window that rises up and down automatically brings convenience to the operator and also brings safety problems. It exits the risk of clipping human arms when window is rising up. Therefore we must take certain measures about anti-pinch to improve the safe of power windows. The anti-pinch system of electric windows described in this article can effectively solve the risk of safety on power windows without affecting the vehicle comfort and power windows working normally.

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THE CURRENT CHARACTERISTICS OF WINDOW MOTOR

Window motors have the following relations between voltage and current:

$$U(S) = (\frac{K2}{JS + f} + \frac{R + LS}{K1})I(S)$$

R is motor equivalent resistance. L is motor equivalent inductance. I(s) is Laplace transformation capacity of motor current. U(S) is Laplace transformation capacity of motor voltage. f is the resistance and friction while motor rotating. J is rotary inertia. S is Laplace operator. K1 is motor back-EMF coefficient. K2 is motor torque coefficient. As the voltage across the motor, rotary inertia J, the equivalent inductance L, resistance, and K1, K2 for a certain motor system can be defined as a constant. When the resistance f increases, the relationship established maintains, so I (S) will be greater. That is, when the windows meet barrier on rising, it will lead resistance increased, so motor speed is smaller and current increasing. So we can determine the size of motor resistance suffered indirectly by sampling motor current.

In the process of the window up or down movement, the electrical current's characteristics shown different in different stages and concern with the resistance formatted by the window transmission, the time of automobile windows using, the differences between the assembly process and window working voltage. In order to understand the real relationship between the current of window working and the window motor movement, it must analysis the motor current characteristics indifferent windows working environments. We only need to research the motor current characteristic when window rising, because the anti-pith function of power window starts only in the process of auto-rising. Fig.1 shows the motor current changes in two different operating voltages when the windows normal rose. It can be see that the motor has rush current approximately 9.5A at the start, and then motor current decreases with increasing speed into a stable state, but Window motor produces a block current approximately 10AWhen the windows reach the peak. The motor's working current in14V working voltage is greater than the current in12V working voltage overall.

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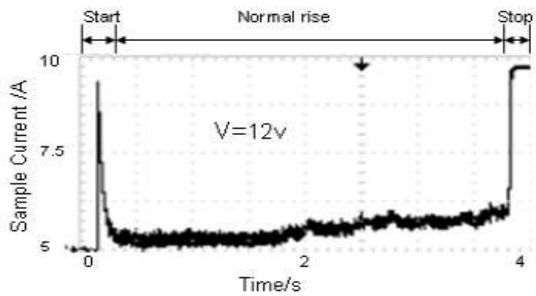
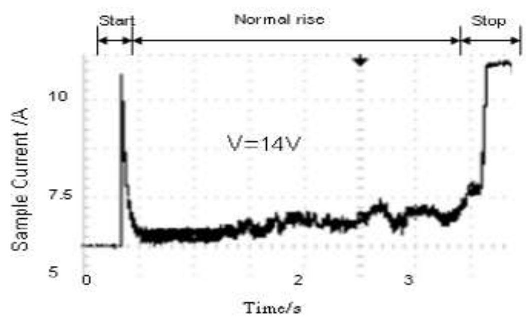


(a) Output current curve when window motors work in the 12V voltage



(b) Output current curve when window motors work in the 14V voltage

Figure 1 The current waveform when window motors work in the 14V voltage

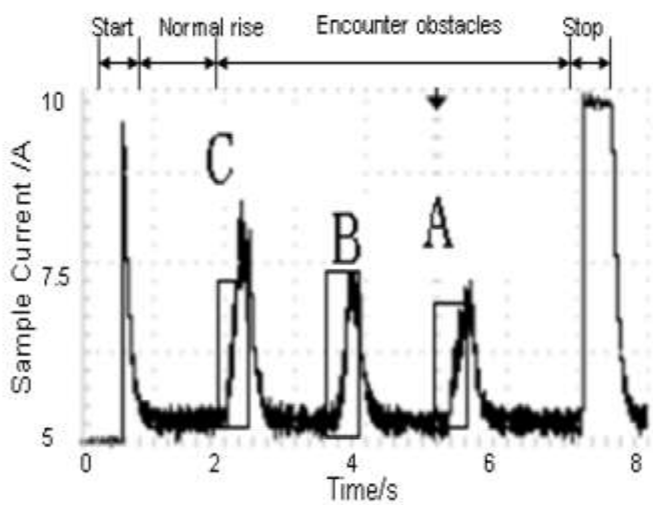


Figure 2 The current waveform when the window encounters obstacles during up

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Fig.2 shows the current changes when window meetingbarriers during rising. We can see that the motor current willincrease when window meets barriers(the current curvebetween the three points of A,B,C in Fig.2).Motor current willincrease correspondingly when resistance increases.(theresistance on point C is greater than the resistance on point Bin Fig. 2)

We can get the characteristics below according to the experimental data of figure 2[4][5]:

a) Current presents the trend low to high when the window

b) rises normally. That is the motor's current increases graduallywith the window rising.

c) There is a transient pulse when motor starts. Then itappears great locked-rotor current after window reaching thepeak. Locked-rotor current is greater than starting pulsecurrent.

d) The current will become greater when window meets resistance man-made, and the current is in direct proportion tothe resistance.

e) Supply voltage impacts the windows rise time and the current value. It can be seen that the value of window motor current canreflect the campaign status of the window. So the value ofwindow motor current can be used as the main basis of judgingwhether window meets blockage or locked –rotor.

THE ANTI-PINCH TECHNOLOGY WITHOUT SENSOR

Now non-sensor anti-pinch measure adopts rippletechnology widely. But rippletechnology requires the windowmotor and DC power very strictly, and it is difficulty realize with software. By analysing the motoroperating current, weknow that the motor operating current is proportional to output torque and it reflects the real situation of motor force, whichcan be used as the main basis of whether window meetingobstacle or reaching the top. Nowadays the main measures to realize window anti-pinch by motor current amplitude areamplitude method, slope method, integral method[6].

It can be see that the motor current's characteristics show different in different stages under normal circumstances from Figure 2. It produced more false positives by using currentamplitude method, what is due

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to the motor current instabilityand sampling error when the window reaches the edge. Thismeans that current amplitude cannot be used to determine whether the window is interruption or not. In order to realizeanti-pinch, it must deal with the current waveform accordingly,and then and then analyse the results of treatment. Slope method uses current change rate as the basis of judge.

The motor current change rate is the largest when window reaches the top, the current is smaller when motor meetsobstacles, and the current is the smallest when motor worksnormally. Suppose that motor current change rate is Kmaxwhen window reaches the peak, and the threshold rate is Kobst whenwindow encounters obstacles. If the current change rate across two points is larger than Kobst and smaller than Kmax , wecan judge that window encounters obstacles.

The programming of current slope method is simple, it can realize the windowanti-pinch function, and overcomes the disadvantage of currentamplitude method, reducing the number of false judgments.But it is difficult to definite the space of time Delta t, whether Delta tis too large or too small, it will effect slope value.

Moreover slope method is very sensitive to the current instantaneouschanges. The output current may cause instantaneous transition,when the motor interference during operation. At this time, thechange rate of the motor current (dI/dt) may reach anti-pinchthreshold, resulting in misjudgement.

$$K = \frac{I_b - I_a}{t_b - t_a}$$

In order to reduce misjudgement, improve the algorithm's stability and reliability, we improve the two methods above, so the integration method is proposed. Integration method is that it calculates current curve area S within a fixed time T, using Sas the basis of judge. In figure 2, the bottom equation of rectangular box on point B is Io = min I(t)

(to<t1<t2)

We can calculate the area

$$S = \int_{t0}^{t1} (I(t) - I_0)dt$$

Which is circled by current curve within the fixed time 1 0 T = t − t , the bottom and the two height of the rectangular box. If the motor current It in the time t is larger than

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the blocked threshold current Iobst, and S is larger than the threshold area Sobst within the fixed time T, we can judge window is blocked. The choice of the blocked threshold current Iobst, fixed time T and the blocked Threshold area Sobst will effects the accuracy of judging whether the window is blocked directly.

Selection of a fixed time T should be determined according to the current actual shape when the motor is blocked. The fixed time's T width must be at least able to cover from the hampered beginning to the current value reaches blocking threshold. Current value should be captured as much as possible to ensure the integrity of the current feature extraction.

But the fixed time T should be not too long, or else easy to produce false positives. The blocking current threshold Iobst and the integral area threshold Sobst are determined by many more experiments averaging method.

THE ANTI-PINCH FUNCTION HARDWARECIRCUIT WITHOUT SENSOR

Window motor now mainly is derived by using automotive relays and integrated H bridge driver IC. As the automotive relays response slowly, are easy interfered by external electromagnetic, have short live and so on. This system uses two half-bridge power drivers IC Infineon's BTS7960B to constitute an H bridge for driving a car window motor.

BTS7960B is half-bridge structure, and has a high MOSFET driver tube and a low MOSFET driver tube in the chip. Its DCwork voltage range is wide (0-43V) and the normal operating current up to 43A.It has over-voltage under-voltage, over temperature, over current, load short-circuit protection, and low self-power consumption. This drive has perfect performance, and can reduce the size of the power windows controller, improves the EMC.

The Fig.3 power windows motor drive circuit and the anti-pinch circuit are part of window controller circuit based on CAN bus [7]. In Fig.3, U2 and U3 are half-bridge drivers IC BTS7960B for automotive. BTS7960B's OUT pin is high output, can drive the window motor directly. INH and IN are control pins for the MOSFET control switch, compatible with TTL level, can be directly connected to the micro-controller's output pins.

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The low-MOSFET is on when INH is high level and IN is low level. The high-MOSFET is on when INH is high level and IN is high level. The pin IS is image current output of load current. The image current has the following relationship with load current.

$$I_S = \frac{I_{Load}}{8500}$$ (I_{load} is the motor's operating current)

R3 is sampling resistor with value of 1KΩ .

The voltage value across R3 is

$$V_{R3}=I_{load}/8.5 \text{ (V)}$$

PIC18F258 microcontroller samples the voltage value across the sampling resistor R3through its AN3 pin, and the sampling signal is changed into digital signal by AD conversion (Reference voltage of AD conversion is 5V). This digital signal is processed, and then compared with the anti-pinch threshold to determine whether the window encounter obstacles.

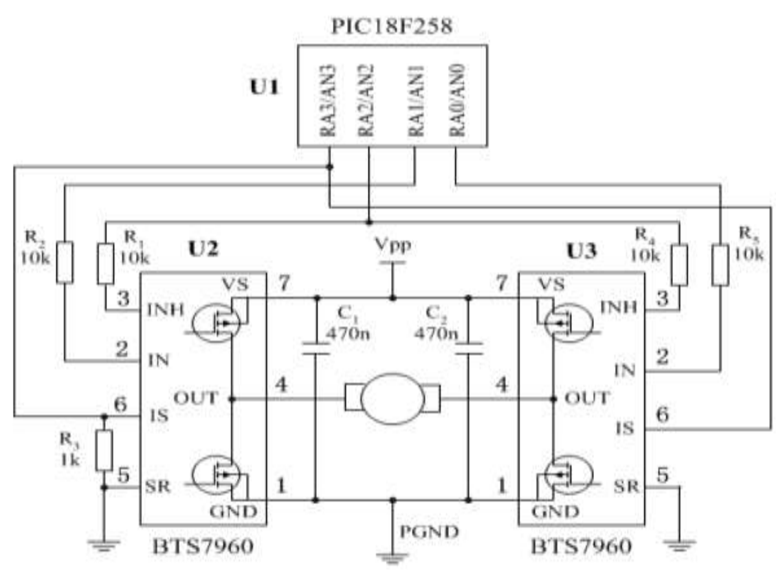

Figure3. The hardware circuit of anti- pinch system without sensor

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THE SOFTWARE DESIGN OF ANTI-PINCH BASED ON THE INTEGRATION

In order to realize software programming more easily, it makes the following improvements on the method of integral:

1) Suppose that current value is sampled $n = \frac{T}{\Delta t}$ times in the T time interval, and requested motor current sampling time is less than Δt.

2) The area enclosed by current curve with the bottom edge and two highs of the rectangle is:

$$S = \frac{T}{2} \sum_{m=1}^{n} (I_{m-1} + I_m - 2I_{\min})$$

In the above equation, Im is current sampling value in the time Tm. I min is the minimum current value in n sampling points.

The software flow pattern is in Fig.4[8][9] :

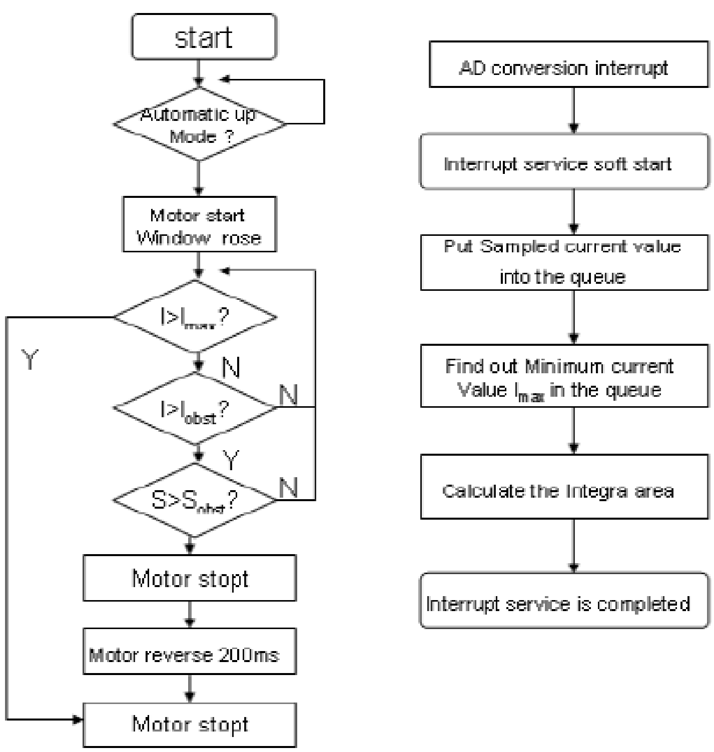

Figure 4. Software flow pattern

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Anti-pinch function starts only when the power windowsautomatically rise. As the current rises up highly whenwindows reach the peak, we can accurately determine whetherthe window reach the peak, by comparing the sample current Iwith the peak current Imax. If sample current value I is greaterthan the anti-pinch current threshold Iobst in the windows upprocess, it also need to compare the integration area S of theperiod time T with the anti-pinch integral area threshold Sobst.

We can determine windows pinch object only when I>Imax andS>Sobst the same time established. If any of inequality does not hold, then MCU re-scan and check current. When the window pinch objects, the motor stops immediately, and then reverses in 200ms to let the glass fall some distance. It generates an interrupt when each AD conversion is completed, then enters the interrupt service. Interrupt service moves the value of the queue table to the left one bit, then assigns the new sampling current value to the table [0], and then finds out the minimum value of the current Imin in the queue by the method of comparing one by one. Finally calculate the integration area S according to the value of the queue. The total time of AD conversion and interrupt handling is about □t.

CONCLUSION

This article describes the anti-pinch measures without sensors using the amplitude method and the method of integral. It intently reduces the number of false positives, greatly improves the reliability and effectively avoids the clip body accidents, which has practical value. The anti-pinch parameter emerges for a particular model window, the anti-pinch parameters for different type windows have to be determined by experiment. We should add adaptive function in the anti-pinch measures to improve the reliability further.

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