Test and Analysis of Stepper Motor’s Noise in HVAC’s Ventilation Valve

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Abstract. With the application of automotive air conditioning being more popular, higher requirements on automotive air conditioning’s comfort have been put forward, noise is an important criterion about comfort. BDC motor controlling ventilation valve’s noise is mainly caused by brush and commutator, but stepper motor doesn’t have it and stepper motor is cheap and easy-controlling. In this paper, the principle of microstepping drive technology is discussed in detail, the control circuit block diagram and the application of the stepping motor’s control system are introduced. The noise of BDC motor and stepper motor controlling ventilation valve is measured in the semi-anechoic room, BDC motor produces peak noise at the start and stop during the working of motor, stepper motor’s noise is slight and smooth-going; current waveforms have been measured in the microstepping drive, the results show microstepping drive makes current waveform more smooth-going and stepper motor’s noise is lower. So it is a tendance stepper motor will replace BDC motor to control ventilation valve, and the microstepping drive can meet different requirements for merchant’s control.

Keywords: Automobile air conditioning; Stepper motor; Noise; Microstepping.

1. Introduction
With modern car entering into the family gradually, the demand for automobile air conditioning system increased significantly. In order to ensure the comfort of car’s environment like home, air conditioning systems become increasingly complexed, especially the semi-automatic air conditioning and full automation air conditioning. HVAC system can transmit cold or hot air to the car, providing a safe, comfortable, relaxed environment for passengers and drivers and improving the visibility of the car window, it also filters out dust and odor, so this system becomes more and more popular among us. As is known to us, noise is always an important index for automobile air conditioning’s quality. Lower noise can meet the higher requirement of people to the comfort of automobile air conditioning, it also complies with the fastly developing society. [1]

The purpose of this paper is to analysis and compare with BDC motor and stepper motor in the movement of ventilation valve’s noise and choose a less noise motor for the ventilation valve’s control. Stepper motor’s microstepping drive provides a new solution for car manufacturers to meet their different requirements for noise.
2. Steeper Motor’s Control System

2.1. The Propose of Microstepping Drive Circuit
In 1975, American scholar T.R.F Redriksen proposed stepper motor microstepping control method for the first time in the United States in the meeting of motion control systems and devices, as in equation (1) gives the interval angle calculation formula.

\[ \alpha = \frac{360^\circ}{mz^k} \]  

\(\alpha\) as one step angle, \(m\) as the phase number, \(z\) as the rotor teeth, \(k = 1\) or \(k = 2\) according to its control mode; due to the precision manufacturing process, \(m\) and \(z\) is impossible to be bigger, so step angle can't be very small, but microstepping can make \(m\) and \(z\) become big in virtual because it changes the mode of going into current. Normally \(\alpha = 1.8^\circ\), it can be 0.014° after microstepping. [2]

2.2. Steeper Motor’s Hardware System
The figure 1 included five parts: main control circuit, drive circuit, isolating circuit, protection circuit and stepper motor.

The function of each part: main control chip takes stm32 as the controller, it can turn received signal into another signal and send it to driver module, driver circuit makes stepper motor working according to the signals it has received. When the system is over voltage, over current, under voltage circuit etc., protection circuit will be opened to protect it. PC is a friendly interface which human beings can be used to communicate with controller. This system has been used to test the microstepping current of stepper motor for the purpose of analysing the noise of stepper motor. [3]

2.3. Microstepping Drive Circuit
Generally, the working principle of constant PWM microstepping circuit: the timer output pulse, the high level of the pulse lets the trigger condition in high level and lets switch tube in saturated conductivity, the voltage value of the sampling resistance increases as the current increases. When its value exceeds the reference voltage, the comparator sends a low level to the trigger, so it can state in low level. At this moment, switch tube disconnected and the current of sampling resistance is reduced, so its voltage will decrease. When the value is lower than the reference voltage, switch tube conduction again, such sampling resistance current will rise up again. At each change, the rotor will turn a microstepping step angle, figure 2 shows the microstepping drive circuit structure diagram. [4]
2.4. Application of Stepper Motor Control System

As more and more high-end cars using high-performance motor controller such as AUDIO, BMW, low-standard cars began to adopt new generation of air conditioning motor control system, such as stepper motor L99MD0, L99MD1 etc. In order to adapt to the requirement of high efficiency, energy saving, environmental protection of the modern society. L99MD0 uses microstepping drive which can adapt to the different requirements of different customers.

3. Ventilation Valve’s Noise

3.1. Ventilation Valve in HVAC System

Automotive air conditioning mostly adopts HVAC system now, which can offer cooling air and heating air for the car. HVAC has two modes called internal reflux and external reflux, external reflux mains the car is open to outside, so air can be in or out freely. Blowing face, blowing foot and defrosting are another three functions of HVAC, which modes are controlled by ventilation valve. Two modes above and three modes below are always used in combination to meet different requirements for people. As it is shown in figure 4. So it is very important for motor to control the position accurate of ventilation valve. Stepper motor can meet it easily for its accurate positioning.
3.2. Software to Test Noise
There are many noises in the test of HVAC. Each noise must meet the criterion of manufactures. Show in figure 5, ventilation valve’s noise is one in the automotive air conditioning. In the paper, stepper motor and BDC motor controlling ventilation valve’s noise belongs to harmonic which have been test and compared in detail.[6]

The noise test in this paper by a software called PULSE system which is firstly launched by B&K company in Denmark in 1996, it is noise and vibration analyzer system which can work in multi-channel, real-time, FFT, CPB, overall. The software includes 3D analysis and modern display which can show the spectium map used to find the high order harmonic and make analysis.\[7\]

4. Test Results And Analysis

4.1. Noise Test
This test is done in the semi-anechoic in Shashi Valeo. The software is Pulse 19.0. Figure 6 shows the test room and a HVAC unit used to test noise.
Figure 7. Stepper Motor’s Noise in Ventilation Valve. Figure 7 shows the noise of stepper motor controlling ventilation valve’s movement. Each waveform standards for every movement of ventilation valve. The process was test in the mode of overall. When stepper motor isn’t working, the noise was always 20dB which is the backnoise. It can see the noise is smooth-going and the max value is 25dB in the all process.

Figure 8. BDC Motor’s Noise in Ventilation Valve. Figure 8 shows the noise of BDC motor controlling ventilation valve’s movement. Each waveform standards for every movement of ventilation valve. Figure 9 is the amplification of figure 8 fourth waveform. The weak noise is disgust in the start and stop. The normal noise’s level is 3.1sone equal to 31dB. And it is bigger than 25dB of stepper motor’s.

4.2. The Analysis of Microstepping Current
In Figure 10, the controller STM32, L99MD01 driver and two-phase hybrid stepping motor. No microstepping, 1/4Microstepping, 1/32Microstepping’s current and voltage have been test. It can see the differences between different modes. The different microstepping of Noise also can be felt. In Figure 11 to Figure 19, there is commissioning process and result.
Figure 10. Stepper Motor Control System.

Figure 11. Voltage of A and B Phase in no Microstepping State.

Figure 12. A Phase Current When the Speed of Rotor Reaches 100 rpm in no Microstepping State.

Figure 13. A Phase Current When the Speed of Rotor Reaches 200 rpm in no Microstepping State.

Figure 14. Voltage of A and B Phase in 1/4 Microstepping State.

Figure 15. A Phase Current When the Speed of Rotor Reaches 100 rpm in 1/4 Microstepping State.

Figure 16. A Phase Current When the Speed of Rotor Reaches 200 rpm in 1/4 Microstepping State.

Figure 17. Voltage of A and B Phase in 1/32 Microstepping State.
It can be seen that the current has been improved in 1/4 Microstepping state compared to no microstepping, and greatly improved in 1/32 Microstepping state. So it can infer vibration of motor will be improved a lot. When in 1/32 Microstepping state, the noise has been improved a lot.

5. Conclusion
BDC motor will produce the peak noise in the start and stop which is disgusting, but stepper motor producing noise is smooth-going in the all progress, even the max value of noise is lower than the value produced by BDC motor. So stepper motor can easier meet the requirement of automotive air condition’s comfort. It is a tendance that stepper motor will be the main motor to control ventilation valve.

Microstepping can improve stepper motor’ noise in the rotating. It also improves the accurate positioning of stepper motor. Microstepping absolutely provides a new solution for car manufacturers.

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