

Chapter 51

Research on Automatic Automobile Air-Conditioning Controller

Bo Yang, Mingming Wang, Ted S. Huang, Fei Peng and Cong Xin

Abstract In order to improve the comfort of riding vehicles, this paper focuses on the automatic air-conditioning controller by introducing the principle of air-conditioner and the design of hardware and software. The controller controls different actuators to achieve the automatic control of head temperature according to automatic control algorithm. Finally, the experiments revealed that the system is stable to achieve the desired requirements.

Keywords Automatic control · Air-conditioner · Controller · Riding comfort · Hardware · Software

51.1 Introduction

With the continuous development of automotive industry, car owners' demand for riding comfort has been increased. Automatic air-conditioner that can keep the driver's head temperature close to the setting temperature on panel plays an important role in a vehicle and has an positive impact on riding comfort. As the core component and the brain of the air-conditioner, air-conditioning controller controls all movements to provide cooling and heating capacity [1].

Figure 51.1 shows an automobile air-conditioner, which mainly consists of blower, compressor, evaporator, heating core, air mix door motor, mode door motor and other components. The blower intakes air from the air inlet and controls winds' blowing speed [2]. When the compressor is connected to engine by the clutch, it will be operating. The liquid refrigerant flows through the evaporator, and changes into gas by absorbing heat of evaporate, which will reduce the temperature of the air blowing through the evaporator [3]. When the engine starts, the temperature of heating core connected with engine coolant pipe and the air through it will rise

B. Yang (✉) · M. Wang · T.S. Huang · F. Peng · C. Xin
GAC Engineering, Guangzhou Automobile Group CO. LTD, Guangzhou, China
e-mail: yangbo@gaei.cn

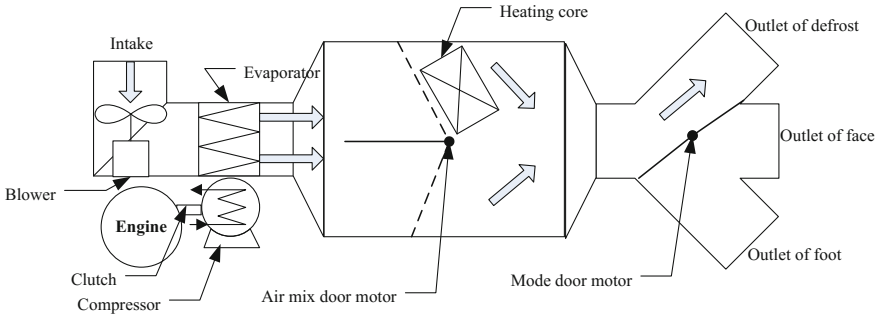


Fig. 51.1 Automobile air-conditioner

rapidly. The air mix door motor controls the ratio of hot air and cold, and the mode door motor controls the direction of the wind blowing out.

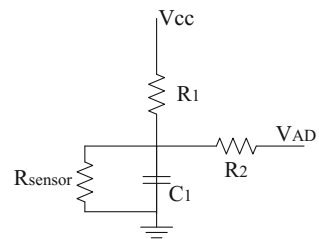
51.2 Hardware Design

Automatic air-conditioner should control all actuators to ensure that the driver’s head temperature is always close to the setting temperature on the vehicle panel according to the change of the ambient temperature, the cabin temperature, the evaporator temperature and sunlight intensity. Therefore, the circuit of automatic air-conditioning controller must include the acquisition circuits to acquire these temperatures and sunlight intensity and the driving circuits to control the blower and door motors [4].

51.2.1 Signal Acquisition Circuit

The resistance of temperature sensor can be changed with different temperature, and the resistance of sunlight intensity sensor can be changed with different sunlight intensity. The signal acquisition circuit is shown in Fig. 51.2, where, R_{sensor} is the

Fig. 51.2 The signal acquisition circuit



sensor’s resistance, V_{cc} is the 5 V voltage in the controller, V_{AD} is the voltage collected by MCU (micro control unit). Finally we will get the temperature or sunlight intensity based on the relationship between temperature and resistance or the relationship between sunlight intensity and resistance.

51.2.2 Circuit for Controlling Blower

The air-conditioning controller controls the speed of blower by providing different driving voltages to the driving module. In Fig. 51.3, a 1 kHz PWM signal sent by the MCU can be switched into a controlling voltage through a high side driver and a two-stage RC filter, which can be changed within a range of 0–5 V by adjusting the duty of the PWM signal.

51.2.3 Circuit for Controlling Motor

Door motor in air-conditioning system is controlled by the servo motor with position feedback, whose position can be calculated by the signal acquisition circuit described in Sect. 51.2.1.

As shown in Fig. 51.4, the MCU controls motors by a half-bridge driver chip, in which MOSI, MISO, SCK, SS are the SPI communication interfaces with MCU. OUT1 to OUT4 are four output ports, which are separately connected with the cold side of the air mix door, the hot side of the air mix door, the face side of the mode door, and the defrost side of the mode door. Take the air mix door motor for example, when OUT1 is high and OUT2 is low, the air mix door motor will rotate to the cold side, when OUT1 is low and OUT2 is high, the air mix door motor will rotate to the hot side, and when OUT1 and OUT2 are both low, the air mix door motor will stop. The MCU could control the motor staying in any position by adjusting the output of OUT1 to OUT4 according to its feedback in real time.

Fig. 51.3 The circuit for controlling blower

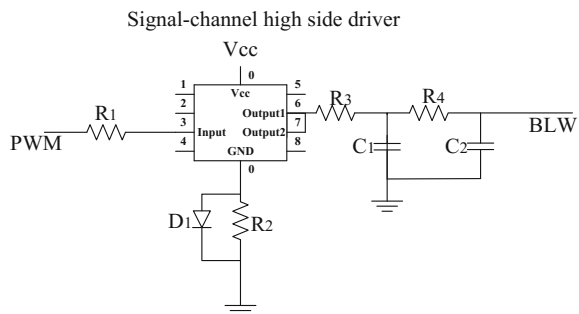
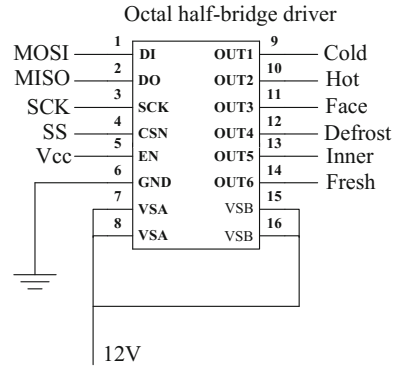


Fig. 51.4 The circuit for controlling motor



51.3 Software Design

51.3.1 Calculation of the Target Outlet Temperature

Target outlet temperature is the key variable of automatic air-conditioning algorithm and directly affects all actuators in the air-conditioning system. It could be calculated by the formula: $TAO = f_1(T_{set}) - f_2(T_R, T_{AM}) - k_1 \times T_S$, where TAO is the target outlet temperature, Tset is the setting temperature, TR is the cabin temperature, TAM is the ambient temperature, TS is the sunlight intensity, and k1 is the sunlight parameter [5].

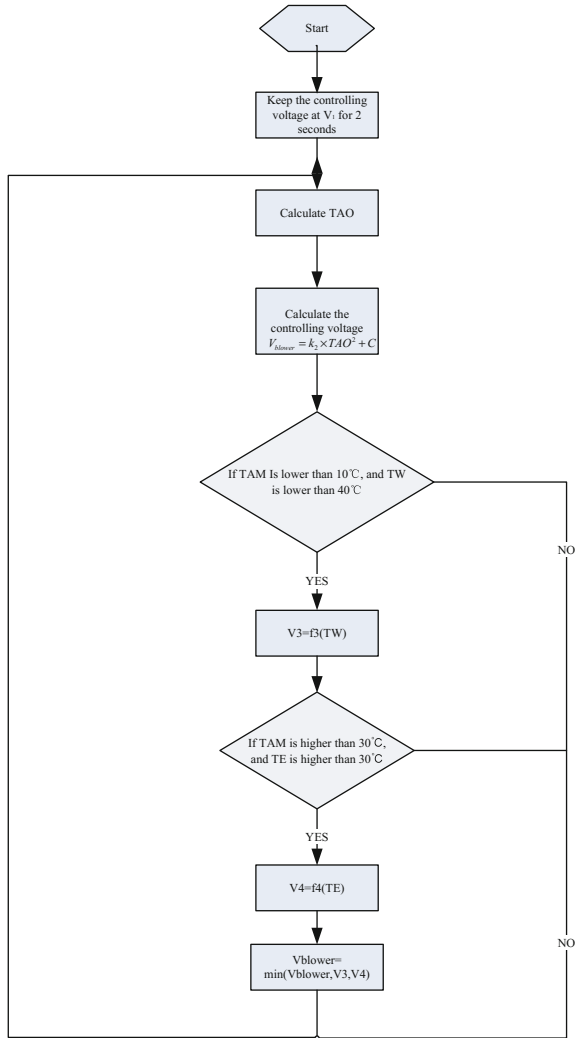
51.3.2 Automatic Control of Blower

Blower is an important actuator of air-conditioning system. Its speed directly determines the wind volume. We should match the starting voltage V_1 depending on the characteristic of different blower types. When the blower is started, the controlling voltage must be kept at V_1 for 2 s to ensure a smooth start and improve the lifetime of the blower.

According to the circuit, the controlling voltage of the blower in automatic air-conditioner is $V_{blower} = K_2 \times TAO^2 + C$, $V_{blower} \in [V_2, 5]$, where k_2 and C are determined by the environment simulation experiment, V_2 is the controlling voltage when blower is 1st wind volume.

In winter, the temperature of engine water (TW) can not rise rapidly to 40 °C slightly higher than the body temperature of human being. In order to avoid blowing out the cold wind, the ECU should do a pre-heating control according to the temperature of engine water. When $TW \leq 40$, $V_3 = f_3(TW)$. In summer, the compressor can not reduce the temperature of evaporator (TE) rapidly. In order to avoid blowing out the hot air, the ECU should do a pre-cooling control according to the temperature of evaporator. When $TE \geq 30$, $V_4 = f_4(TE)$. Finally, the controlling

Fig. 51.5 The automatic control of blower



voltage of blower is determined by $V_{blower} = \min(V_{blower}, V3, V4)$. The flow chart of blower control is shown in Fig. 51.5.

51.3.3 Automatic Control of Compressor

Compressor is the only refrigerating source of automotive air-conditioning system. It compresses low-pressure gaseous refrigerant to high pressure gaseous refrigerant, which will come into the evaporator and take away its heat. When the air sucked by the blower blows through the evaporator surface, it will become cold by heat

exchange. If the compressor has been in operation continuously, it will not only be a waste of engine torque which stands for vehicle energy, but also make evaporator be frozen which may break the air-conditioning system down. If the compressor is stopped, air-conditioner will lose its cooling function. Therefore, in software, when the evaporator temperature is lower than TE_1 , the compressor will be stopped, and when the temperature is higher than TE_2 , the compressor will return to work. $TE_1 = f_5(TAO)$, $TE_1 \in [1, 10]$, $TE_2 = TE_1 + 2$.

51.3.4 Automatic Control of Motor

As shown in Fig. 51.1, air mix door motor allocates the volume of cold air blowing through the heating core, which will come together with other cold air. The position of the air mix door motor that determines the outlet temperature can be calculated by the formula $SWD = f_6(TAO, TW, TE)$, where $SWD \in [0\%, 100\%]$.

According to thermodynamics and related air-conditioning experiences, people do not want the cold air to blow foot and the hot air to blow face. In the software design of automatic air-conditioning controller, the relation between the position of mode door and TAO should be considered. When TAO is higher than T1, the mode door should be at the position of blowing foot. When TAO is lower than T1 but higher than T2, the mode door should be at the position of blowing foot and face. However, when TAO is lower than T2, the mode door should be at the position of blowing foot.

51.4 Experiment Results

In order to verify the effect of the automatic air-conditioning controller, the author conducted an experiment on a vehicle equipped the designed controller in the winter of Heihe and in the summer of Sanya, in which the setting temperature was set at 25°.

In December, the ambient temperature in Heihe is about -20 °C. As shown in Fig. 51.6, after the air-conditioner was started up, the head temperature could reach 25 °C in 20 min, and be at a stable state within 10 min, indicating that the automatic heating control can meet the requirements.

In July, the ambient temperature in Sanya is about 36 °C, the strongest sunlight intensity is about 1 kW. As shown in Fig. 51.7, after the air-conditioner was started up, the head temperature could reach 25 °C in 5 min, and be at a stable state within 10 min, which indicated that the automatic cooling control can meet the requirements.

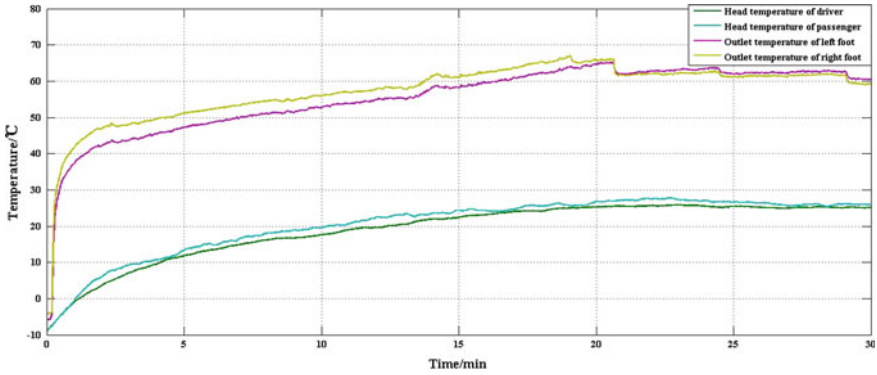


Fig. 51.6 Winter experiment

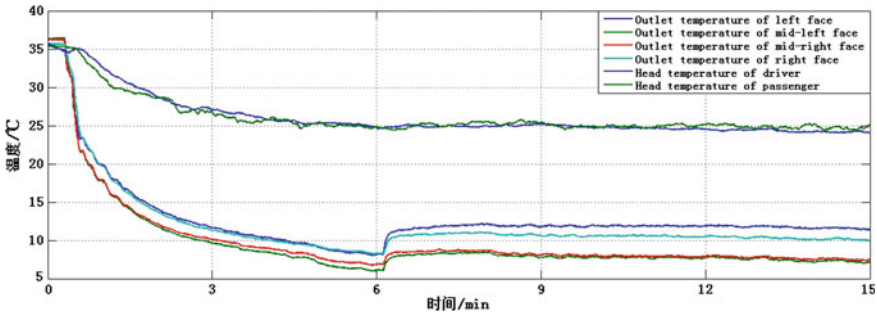


Fig. 51.7 Summer experiment

51.5 Conclusion

This research developed an automatic air-conditioning controller, which controlled the blower, compressor, door motor and achieves automatic control of the head temperature by collecting the ambient temperature, the cabin temperature and sunlight intensity. Experiments on the vehicle equipped with automatic air-conditioning controller revealed that the designed controller is high-precision and helpful for improving riding comfort.

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