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Digital control strategy for scanning of moving mirror in fourier transform spectrometer

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ABSTRACT

The control system of moving mirror scanning is an important part of the Fourier transform spectrometer, and its dynamic and static performance determines the interference effect and the spectral resolution of the spectrometer. To meet the requirement of the uniform velocity of moving mirror scanning, a completely digital control scheme is proposed with FPGA as the key hardware, and this scheme is applied to the moving mirror movement in the spectrometer. According to the need of the current detection and the velocity detection, a dual closed loop control composed of current loop and velocity loop is realized, with current loop and velocity loop using PI control and fuzzy PID control respectively. The experiment results show that the current curve is smooth in the uniform scan phase of moving mirror, and that the peak current is 0.5 A in acceleration and deceleration period. Additionally, when the angular velocity of moving mirror is 30°/s in the uniform section, the maximum relative error is less than 4%. From research results, it can be drawn that the digital control strategy can significantly improve the velocity stability of moving mirror, and meet the performance requirements of the control system.

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1. Introduction

As a widely-used high-resolution spectrometer, the Fourier transform spectrometer can get the interferogram through the modulation of interference signal strength by the moving mirror scanning, and then acquire the spectrogram through the Fourier transform of the interferogram [1]. The moving mirror is the only moving part in the Fourier transform spectrometer. If its scanning velocity is not uniform, the interferogram data processing will be affected and “ghost lines” may emerge in the spectrogram. On the other hand, if its maximum trip corresponds to the maximum optical path difference in the spectrometer, then increases in optical path difference can improve the spectral resolution. Therefore, the control precision of the moving mirror’s scanning system directly determines the performance of the Fourier transform spectrometer [2,3].

In traditional Fourier transform spectrometer, the stepper motor or the voice coil motor is often used to drive the moving mirror. The stepper motor is good for its precise position control, but its change in the instantaneous velocity is too abrupt, thus unable to be in sustained uniform motion. Contrary to the step motor, the voice coil motor has the characteristics of simple structure, small volume, high speed and fast response. When combined with the closed-loop control system, the voice coil motor can achieve the task of highly precise servo control [4,5].

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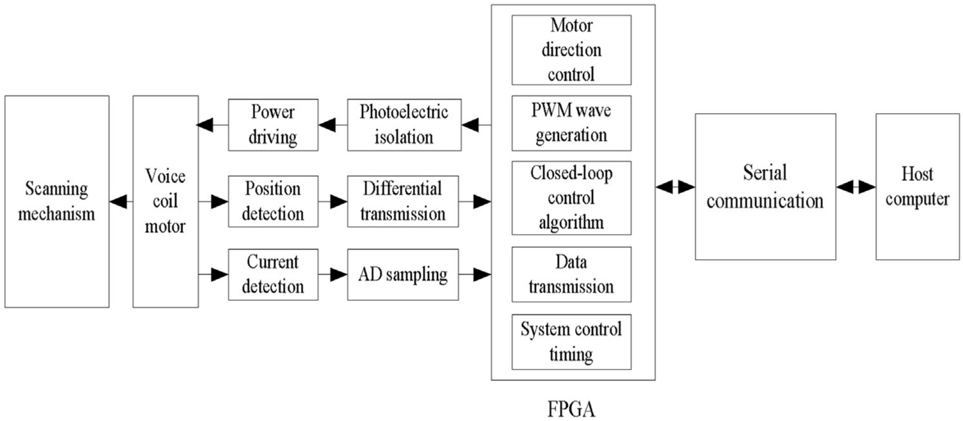

Fig. 1. The hardware block diagram of the driving and control system.

The servo system of moving mirror scanning is a closed-loop control system with velocity negative feedback, whose closed-loop structure varies according to different working situations [6]. In essence, the moving mirror's driving control system is a closed-loop variable velocity system. In order to ensure rapidity, stability as well as limited current protection of the voice coil motor, the control system adopts the dual closed-loop structure.

This paper proposes a hardware implementation scheme of digital control system for scanning of moving mirror in Fourier transform spectrometer based on field programmable gate array (FPGA) chip APA300. To realize full digital control of the voice coil motor for scanning of moving mirror, this implementation scheme adopts the strategy of dual closed-loop control, which is composed of the current loop and the velocity loop. With FPGA as the control core, the control system employs Verilog HDL hardware programming to realize its control algorithm, and then experimentally verifies the feasibility of this closed-loop control strategy.

2. The principle of the digital control system

In order to improve the stability of the system, the closed-loop control system in the moving mirror uses a dual closed-up velocity control strategy comprised of the current loop and the velocity loop. The inner loop is the current loop. It can transform the transfer function of the inner loop control object, and thus enhance the system's rapidity, namely the fast response to the control input of the outer loop. The outer loop is the velocity loop. It can ensure the system's steady precision and dynamic tracking, which is not only directly related to the stability of the digital control system, but also the main channel for the velocity negative feedback control [7,8].

The moving mirror's driving and control system uses the full digital control mode. This means that the current and velocity of the voice coil motor, onto which the moving mirror is mounted, are regulated and controlled through digital signals. Fig. 1 shows the block diagram of the FPGA-based driving and control system hardware. Included in this diagram are mainly the following modules: the FPGA main control unit, the power driving, the current detection, the position detection and the serial communication.

The FPGA chip APA300, made by Actel company, generates pulse width modulation (PWM) wave, which, together with motor direction switching control signals, can be isolated by optical couplers. When sent later into the H bridge power driving module, the PWM wave and the control signals can drive the voice coil motor mounted with the moving mirror's scanning mechanism. The motor current flows through the Hall current sensor, acquires the voltage signal through the signal adjusting circuit, and then is converted from the analog signal to the digital signal by the A/D converter circuit. At the same time, moving mirror's angular displacement is being tested by the photoelectric shaft encoder, whose output is orthogonal signals. After the differential receiving circuit processing, these orthogonal signals acquire the position information. Then the current and the position information are transmitted to FPGA, and dual closed-loop control algorithm is completed in FPGA, so that the real-time control of moving mirror scanning's uniform velocity is thus fulfilled. The drive and control circuit board based on FPGA is shown blow in Fig. 2.

In order to realize the velocity closed-loop control, the driving and control system of the moving mirror scanning needs to acquire the velocity signal of the moving mirror. However, in the full digital closed-loop control system, the velocity sensor is not directly used, instead the photoelectric encoder is the choice position sensor, which acquires the velocity signal by processing the position signal from the photoelectric encoder. It should be made clear that sampling intervals should be set in FPGA. In this way, the moving mirror velocity can be determined by counting the position pulse of the frequency subdivision, and the moving mirror scanning direction can be obtained through the direction discrimination circuit. Then the direction signal is connected to the FPGA internal module – the digital frequency meter, which is responsible for adding

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