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Design of stable speed control system of measuring base station for large space precise positioning

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Abstract: High-precision laser positioning system (ALPS) is a sub-millimeter level distributed indoor positioning system. In view of the low scanning accuracy of ALPS base station and the accuracy of real accuracy, a new speed control system is designed. The steady speed control scheme based on PID and hardware phase-lock loop control, loop filter and series correction circuit are designed, and the embedded software for steady speed control is designed to ensure the stability and reliability of the system. Through experimental verification, the results show that the loop control is normal, and the stability error is within ± 2.5 r/min, which expands the application range of high precision indoor positioning of ALPS system.

Keywords: ALPS; Hardware Phase Locking Ring; Series Correction; Steady Speed Control

1.Introduction

ALPS is a kind of combination of GPS principle and rendezvous measurement principle of typical distributed laser measurement system, compared with the traditional measurement system, its flexible layout, measurement range, measuring point, high accuracy, can be widely used in intelligent robot indoor positioning navigation, aircraft rocket flexible assembly process [1-3]. Among them, the base station uses the high-speed rotation of the motor to drive the line laser on the transmitting head for scanning and measurement, and the photoelectric receiver receives the laser information of different base stations, the processor transforms the optical information and the moment information, and performs the position calculation. The speed stability of the measuring station finally affects the accuracy of information extraction at the laser scanning time [4].

Traditional speed control methods generally need to meet the requirements of position control accuracy and speed control, while PID control and FOC control methods can take into account the requirements of speed and position control to ensure the normal operation of the system [5,6]. However, using the above method, the stability speed error of the station is greater than 10 r/min under 3000 r/min, and the real-time positioning accuracy of the system is greater than 1mm. In order to improve the positioning accuracy, the speed accuracy is increased to 3 r/min by multi-circle averaging method to ensure the positioning accuracy is better than 0.2mm; but this method reduces the real-time positioning speed from 50Hz to within 5Hz, which is difficult to meet the real-time requirement of indoor positioning and navigation of the mobile robot, which limits the application scope of the system. Therefore, this paper will adopt the double closed loop steady speed control method to realize the high precision steady speed control of motor operation.

For the problem of low standing speed performance and difficulty to guarantee the system positioning accuracy, this paper proposes a high-precision speed stabilization control scheme combining PID and hardware control circuit, design, and expand the application scope of high-precision indoor positioning of ALPS system.

2.Steady speed control scheme design

In the field of motor control, the phase-lock loop is a method [7] of comparing the reference signal frequency with the feedback frequency of the position sensor, so that the feedback frequency of the position sensor constantly approaches the reference frequency, so as to control the constant rotation speed. The advantage of this method is that once the system enters the locked state, the output frequency can be adjusted in real time to ensure that the system can stabilize at the frequency in high precision, so as to meet the high stability requirements of the system. In addition, the single control mode has the risk of locking loss, and the system exceeds the locking frequency range, resulting in the closed-loop feedback failure; Therefore, this paper introduces the PID control method to realize the speed closed-loop control, to provide conditions for the system to enter the phase-locking state again, to avoid the system stall. The overall scheme is shown in Figure 1.

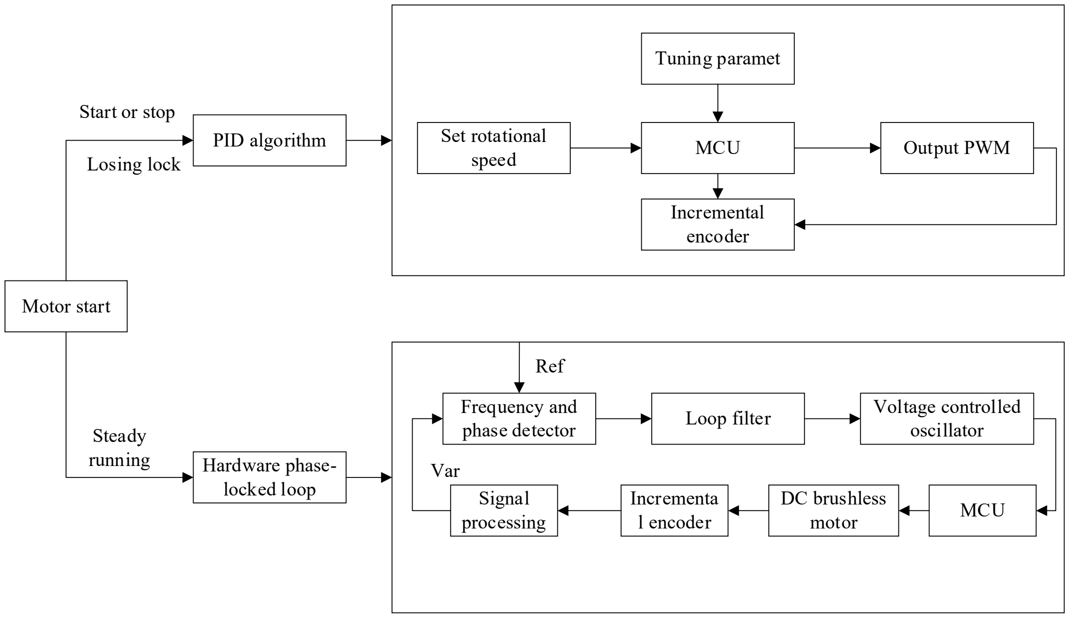

Figure 1. Overall scheme diagram

Its working principle is shown in Figure Figure 1. Incremental PID is used to start the motor to adjust the speed. When the speed reaches the target threshold, switch to the phase-locked loop control motor. In the steady speed operation stage of the motor, the two input signals of the phase locking loop system have equal frequency, the phase difference is fixed, and the locked state is maintained. If the speed change range is large due to some external factors, exceeding the locking range of the PCL, the controller switches to the PID control mode for rapid adjustment, so that it can reach the "locking" condition again, and continue to use the PCL to adjust the speed steadily.

3.Design of PCL circuit

The phase-locked loop control circuit includes three parts: frequency-phase detector (PFD), voltage-controlled oscillator and loop filter [8]. In the design scheme, the frequency mirror phase detector and the voltage-controlled oscillator are integrated into the phase-locked loop chip CD74HC4046A. In this paper, the frequency range of the voltage-controlled oscillator should be set, and the loop filter and series correction circuit are designed to meet the requirements of system steady speed control.

3.1 Pressure-control oscillator frequency setting

The CD74HC4046A Voltage-controlled oscillator frequency is determined by external capacitor C 1 and two resistors R 1 and R 2, where R 1 and capacitor C 1 determine the VCO frequency range, the resistor R2 allows the VCO to have a frequency offset, i. e. a range of output frequencies can be specified.In this paper, the center frequency of the integrated PCL chip VCO was determined to be 200 KHz and the offset frequency was 48 KHz. The output frequency of VCO and external components 1 shown in Figure 2, the value of C1 is 1 nf, R1 is 15K and R2 is 150K.

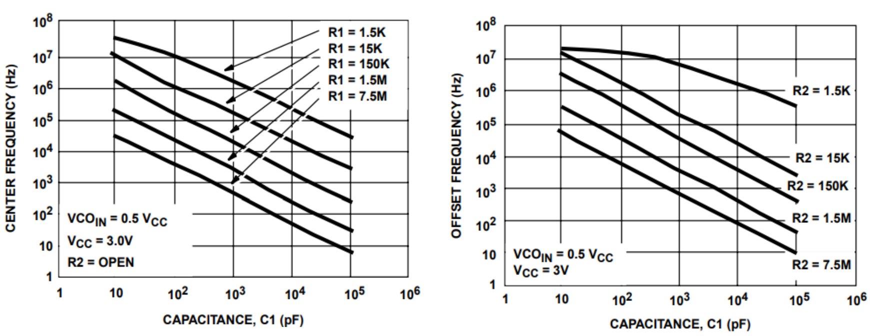

Fig. 2 Output Frequency of VCO vs. External Components

3.2 Loop filter and series design and correction design

The loop filter includes a second-order Butterworth filter outside and an inverter, and the schematic diagram is shown in Figure 3.

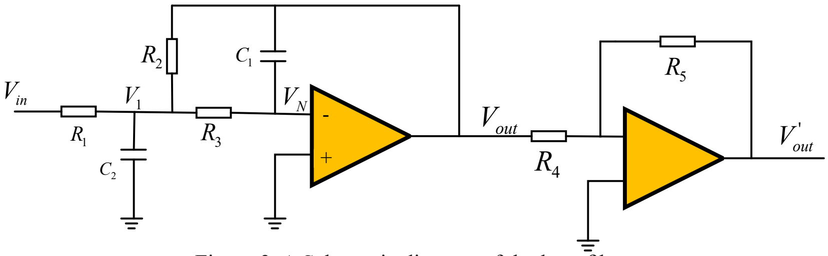

Figure 3. A Schematic diagram of the loop filter

According to the circuit of FIG. 3, the principle of short and short can be obtained:

$$\begin{cases} \dfrac{V_{in} - V_1}{R_1} - \dfrac{V_1}{1/sC_2} - \dfrac{V_1 - V_N}{R_3} - \dfrac{V_1 - V_{out}}{R_2} = 0 \\ \dfrac{V_1 - V_N}{R_3} = \dfrac{V_N - V_{out}}{1/sC_1} \\ V_N = 0 \end{cases} \quad (1)$$

The transfer function of the loop filter that can be solved by the combined vertical upper formula is:

$$A(s) = \frac{\dfrac{R_2}{R_1}}{1 + sC_1\left(R_2 + R_3 + \dfrac{R_2R_3}{R_1}\right) + s^2C_1C_2R_2R_3} \quad (2)$$

So, in the design of this topic, the target speed of the motor is 3000 r/min, so the reference frequency is set to 500Hz. To effectively filter, the frequency of the output of the filter is set between 50 Hz and 100 Hz. This topic, the frequency of the filter is designed as 65Hz, and the gain is 1, that is, the shear frequency of the control system should meet 408.4rad/s, through the above parameters can be obtained: R1=R2=10K, R3=3K, C1=0.1uF, C2=1uF.

In order to ensure the stability of the control system and improve the dynamic performance of the system, the first-order advanced series design correction hardware circuit is designed as shown in Figure 4.

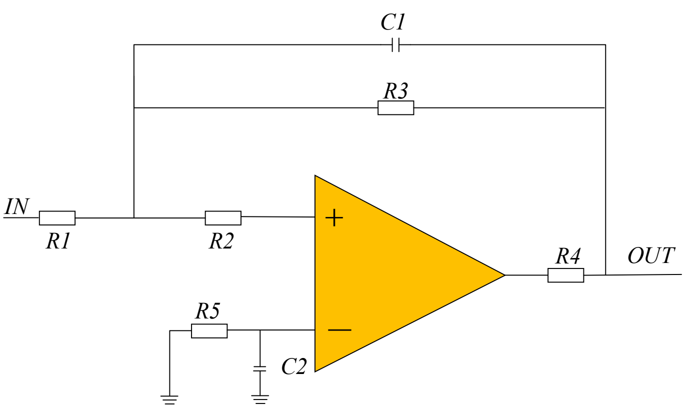

Figure 4. Schematic diagram of the series design correction

By selecting the appropriate advanced network parameters, and the phase margin is increased to, the stability of the control system is guaranteed, the crossing slope of the system at the shear frequency is-20 db / dec, and the open ring gain of the system is improved. In the high frequency band, the system decays at-80 db / dec speed, which can well suppress the high frequency noise and improve the dynamic performance of the system to meet the design requirements.

Combined with the CD74HC4046A chip peripheral reference circuit, the phase-lock loop control circuit is designed, as shown in Figure 5.

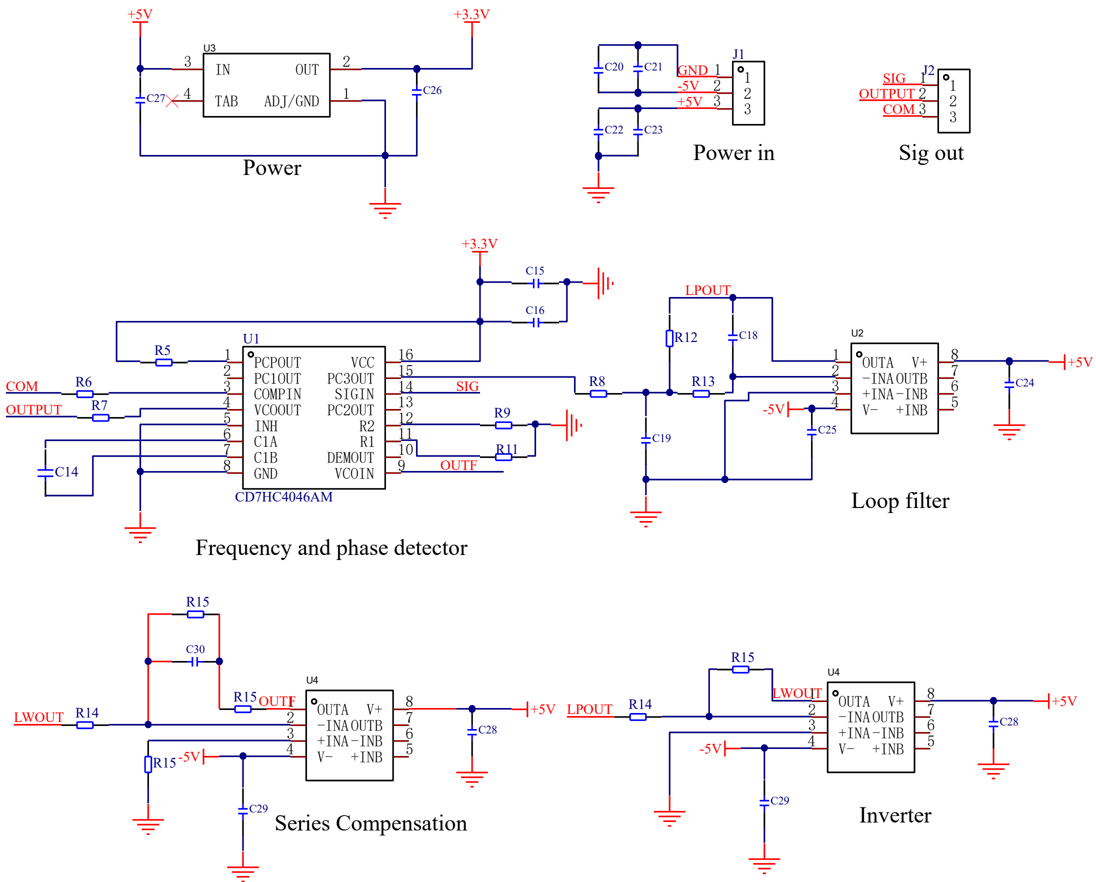

Figure 5. Schematic diagram of the PLL system

4.Software design of steady speed control system

The overall flow chart of the software design of the steady speed control system is shown in Figure 6. PID control is used to “rough adjustment” of the motor speed, and the speed is “fine tuning” by phase-locked ring control. The microcontroller first detects whether the target speed reaches the “lock condition”, and then enters different interruption control procedures according to the judgment results. If the target speed threshold is not reached, the PID algorithm will be used to control the speed, and the parameters of the PID algorithm have been pre-adjusted to the best control effect. If the microcontroller detects that the real-time speed has reached the “locking condition”, the Plock control system will be used to correct the target speed, the microcontroller will extract the output frequency of the VCO into the phase difference between the current reference signal and the feedback signal, judge whether the feedback signal is ahead of the reference signal, and then change the duty cycle. Finally, the microcontroller performs the phase program of the motor.

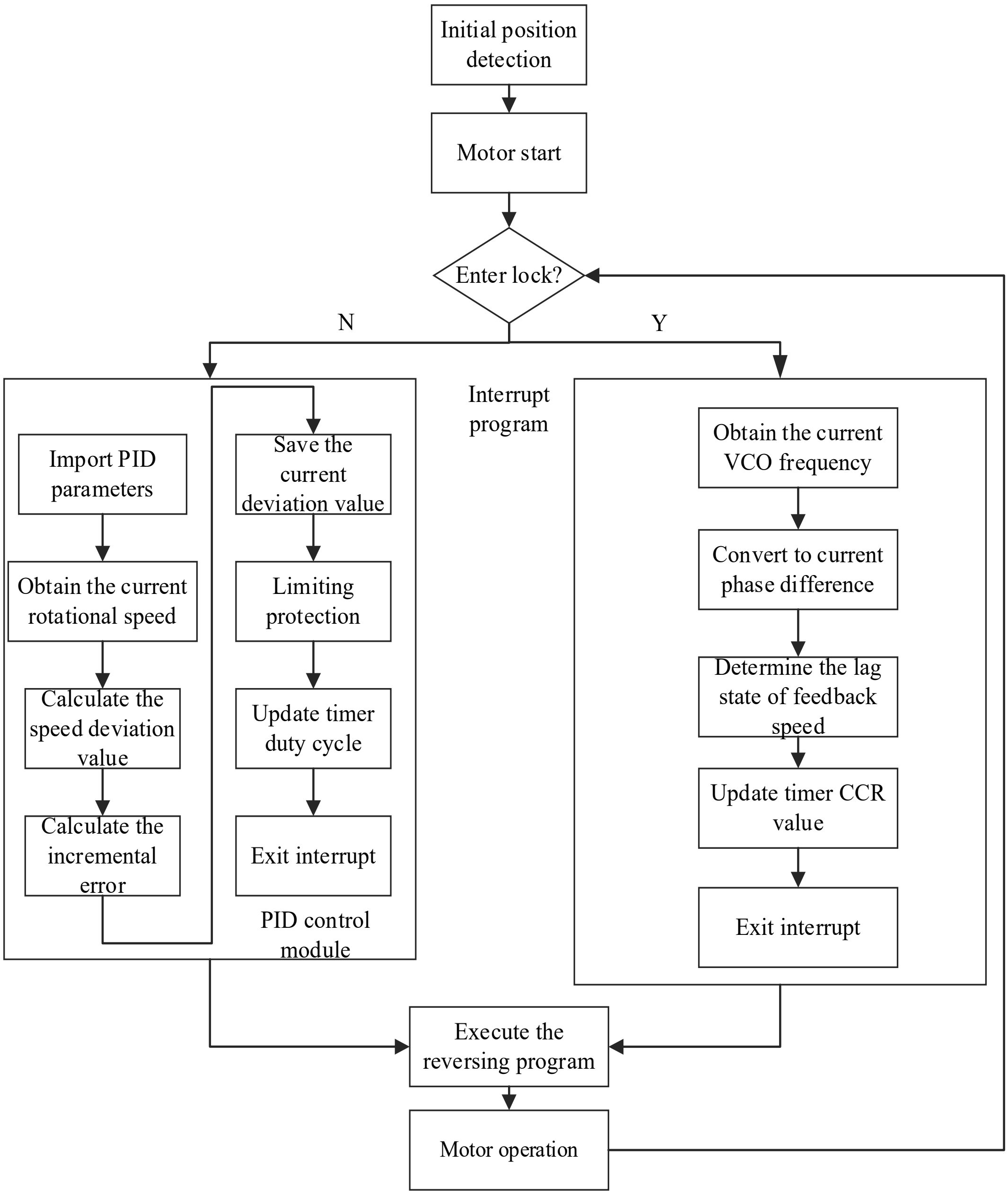

Figure 6 Overall block diagram of the embedded software design of the steady speed control system

5.Steady speed control experiment

With the existing station servo motor as the load, the designed Plock module is added to the original control module to conduct the motor speed control experiment. The experimental platform is shown in Figure 7.

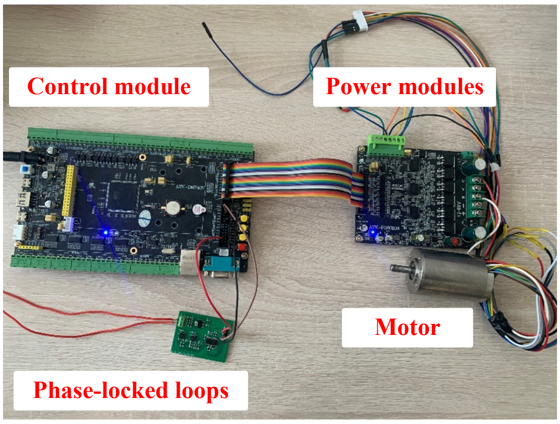

Figure 7. Experimental platform

In the steady speed control experiment, the microcontroller collects the signal output by the position sensor and calculates the motor speed, and sends real-time data through the serial port. The software sets the serial port for 1min to sample the motor speed data and save it, as shown in Figure 8.

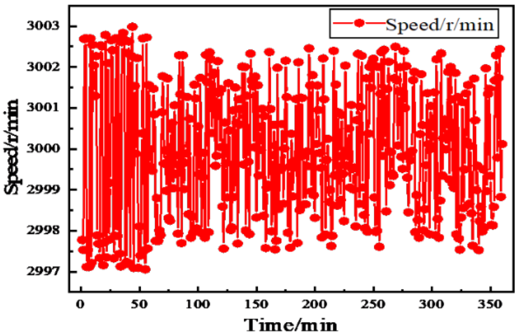

Fig. 8 Motor rotation speed: 3,000 r / min rotation speed

The experimental results show that the real-time speed of the motor collected within 6h fluctuates greatly within 1h before the motor starts, because the transmitting base station does not preheat the best state, and the long stabilization error of the motor is within ± 2.5r. The experimental results confirm that the stability and reliability of the steady speed control can meet the real-time positioning requirements of industrial field measurement.

6.Conclusion

In order to solve the low ALPS base station scanning accuracy, it is difficult to ensure the system real-time positioning accuracy, this paper puts forward a kind of loop combined with PID steady speed control method, designed the integrated loop filter, series correction and integrated loop module high stability of loop hardware circuit, and the software fusion PID algorithm, reduce the stall risk of the control system. Through experiments, the error of steady speed is within ± 2.5 r/min, which provides a basis for the subsequent productization of high steady speed base station.

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