

Servo Platform Circuit Design of Pendulous Gyroscope Based on DSP

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Abstract. In order to solve the problem when a certain type of pendulous gyroscope in the initial installation deviation more than 40 degrees, that the servo platform can not be up to the speed of the gyroscope in the rough north seeking phase. This paper takes the digital signal processor TMS320F28027 as the core, uses incremental digital PID algorithm, carries out the circuit design of the servo platform. Firstly, the hardware circuit is divided into three parts: DSP minimum system, motor driving circuit and signal processing circuit, then the mathematical model of incremental digital PID algorithm is established, based on the model, writes the PID control program in CCS3.3, finally, the servo motor tracking control experiment is carried out, it shows that the design can significantly improve the tracking ability of the servo platform, and the design has good engineering practice.

1. Introduction

The prototype of this paper is a type pendulous gyroscope of the PLA 1001 factory, which can reach the north precision of 5", and the north time of the north is about 12min, and the overall performance reaches the international advanced level. But when the equipment is in the initial Angle is greater than 40 degrees north, there will be a problem that servo motor can not to track the gyro motor, leading to the failure of the coarse search north. The paper^[1], from the perspective of the coarse search north algorithm, tried to solve this problem by improving algorithm, while from the point of practical experience, the root of appearing this kind of problem often lies in the control of the servo motor, due to the original control scheme is too simple, causing the failure gyro motor servo motor tracking.

This paper based on digital signal processor (DSP) as the core control component, the circuit of gyro north finder found servo platform is designed, and gives the corresponding algorithm, finished the platform tracking experiment, proves that the new scheme can improve the tracking performance of the servo platform.

2. Servo Platform Circuit Design

The circuit of the platform is controlled by DSP, and the model is TMS320F28027 produced by TI company (hereinafter referred to as 28027). DSP is the abbreviation of digital signal processor, compared with the traditional single chip microcomputer, the advantages of DSP are: high speed, low power consumption, support complex control algorithm, convenient for advantages of signal processing and high cost performance^[3].



2.1. Minimum system design of 28027

28027 is a 32-bit fixed-point processor, have 8 enhanced PWM output and 16 road high speed ADC, the configuration of up to 22 with input spike pulse filter function multi-function reuse GPIO pins, suitable for the servo control of the machine.

2.1.1. Power circuit design. The power supply of 28027 is 3.3V, and the internal existing digital device also has emulator parts, in order to avoid the noise interference, the 28027 power supply is divided into digital power supply and analog power supply. 28027 power circuit is shown in figure 1, the AMS – 1117 transfers 5 V power supply which system provided into 3.3 V, with a 47 uF polarity capacitance for low frequency filtering and a 100 pF non-polar capacitors for high frequency filtering. The digital power supply is separated from the analog power supply and connected by inductance.

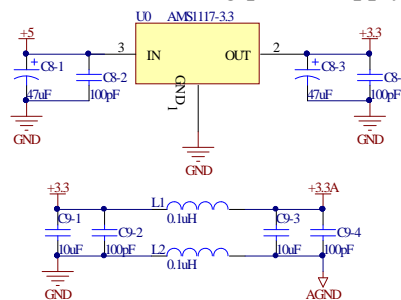


Figure 1. 28027 power supply circuit.

2.1.2. Clock circuit design. 28027 supports two clock generation modes, which can be input to XCLKIN pins by means of a crystal oscillator or an external clock. In order to simplify the circuit, the internal crystal oscillator (OSC) is not working. The circuit diagram is as follows:

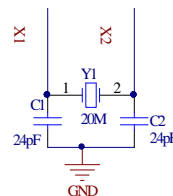


Figure 2. 28027 clock circuit.

2.1.3. Reset circuit design. 28027 with reset function, in order to guarantee the accuracy of the chip reset, reset pulse width should be at least eight oscillator clock, due to some components delayed, for a better reset all devices, delay time should be appropriately extended, reaches more than 100ms. The design $R = 10K$, $C = 10uF$, the reset time is about 230ms, and the crystal oscillator itself is stable to meet the reset demand. On the basis of RC circuit, manual reset function is set up to facilitate system debugging.

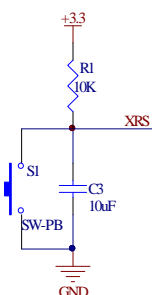


Figure 3. 28027 reset circuit.

2.2. Drive circuit design

The prototype servo platform motor is the Faulhaber dc servo motor. The motor has four pins, which are the servo motor+, the servo motor-, the speed measuring motor output+, and the speed measuring motor output-. The servo motor can be used for direct current, and the speed measuring motor can output the speed of servo motor in real time. The motor specific parameters are as follows:

Table 1. DC servo motor parameters.

Rated voltage 12V	Rated torque 5.9mNm	Rated current 0.43A	Rated speed 4600rpm
EMF constant 1.5mV/rpm	Output impedance ≥ 25	maximum speed ≤ 5000 rpm	terminal resistance 260 Ω

According to the parameters of the motor, the DRV8701 produced by TI company is used as the motor drive chip.

2.2.1. Function description of DRV8701. DRV8701 is the single-channel H bridge gate drive produced by TI company, which is used to drive four external N channel field effect tubes, which can then drive a dc servo motor. The main advantages are: the range of working voltage is wide, which is 5.9 v-45v, and the dc motor rated voltage of the prototype is 12V, which is within the scope of its work; Supports PWM speed control; has low-power sleep mode; It has security functions such as flow protection, heat shutoff, fault state output, etc.

The wiring of DRV8701 is as follows:

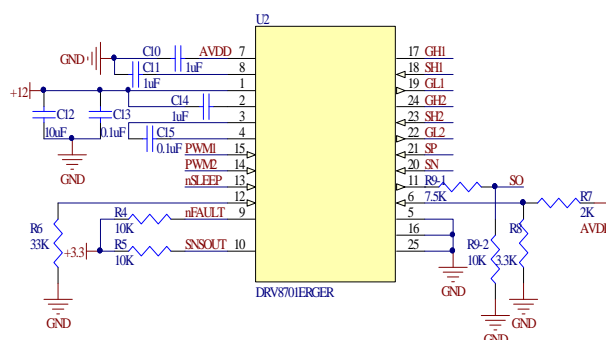


Figure 4. DRV8701 wiring diagram.

The VM is the power supply pin, and the rated voltage of dc servo motor is provided. The PH/IN1, PH/IN2 pins are connected to the two enhanced PWM signal output of the DSP, and change the motor speed by changing the proportion of the space ratio of the PWM; The nSLEEP pin is the sleep control pin. When the pin is low power, the chip is in a dormant state, which can reduce the power consumption and save energy. The nFAULT is the output pin of the fault state, when the output is low power, the current chip is in fault condition. SNSOUT pin is used to protect the chip, and when the output is low, it indicates that the internal current of the chip is too large and is in a state of over-current protection.

2.2.2. Field effect tube circuit. The DRV8701 cannot directly control the dc servo motor, and it needs to connect the motor with the H bridge drive circuit formed by four n-channel field effect tubes. The circuit is shown in figure 5:

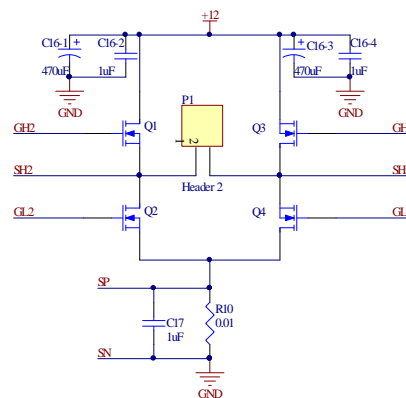


Figure 5. Field effect tube drive circuit.

Interface P1 connects dc servo motor with positive and negative pins. The specific control mode is as follows:

Table 2. Control function list.

nSLEEP	IN1	IN2	SH1	SH2	function
0	X	X	High-Z	High-Z	dormancy
1	0	0	High-Z	High-Z	cut-of
1	0	1	L	H	reverse
1	1	0	H	L	forward
1	1	1	L	L	deceleration

According to table 2, when nSLEEP pins are low current, the chip is in a dormant state, and H bridge is in the closed state, the four kinds of permutations of IN1 and IN2 levels correspond to the four motion states of the motor.

3. Servo motor PID control

The original control scheme is based on the P control of the MCU, which can not achieve the control without error, the control accuracy is low, and the system overtone is larger, resulting in the failure of servo motor tracking. The present improvement is based on the incremental digital PID control based on DSP [7].

3.1. The principle of incremental digital PID control

PID control is the proportional integral derivative control. In the development process of automatic control, PID control is the oldest and most vigorous basic control mode. Its main advantages are: the principle of control algorithm is concise, the physical meaning of parameters is clear, Application experienced in technical maturity, it is adaptable and can be controlled in situations where the internal principle of the control system is not clear.

In this paper, DSP control is used. Since DSP can only recognize the digital quantity and cannot directly calculate the continuous simulation quantity, the PID control law must be discretized.

$$e(n) = r(n) - y(n) \quad (1)$$

In formula 1, $r(n)$ is a given value, $y(n)$ is the system actual output value, $e(n)$ is the difference between given value and actual value.

When the sampling period T is very small, dt can be approximated by T , de/dt can be approximated by $e(n) - e(n-1)$, and the integral can be approximated by the sum. Set the PID output is $u(n)$

$$u(n) = K_p e(n) + K_p \frac{T}{T_i} \sum_{i=1}^n e(i) + K_p \frac{T_D}{T} [e(n) - e(n-1)] + u_0 \quad (2)$$

In formula 2, K_p is the proportion constant, T_i is the integral constant, T_D is the differential constant, u_0 is the initial value of the deviation.

$u(n-1)$ can be obtained from the formula 2:

$$u(n-1) = K_p e(n-1) + K_p \frac{T}{T_i} \sum_{i=1}^{n-1} e(i) + K_p \frac{T_D}{T} [e(n-1) - e(n-2)] + u_0 \quad (3)$$

The mathematical expression of incremental digital PID algorithm is produced by subtract the formula 2 from the formula 3.

$$\Delta u(n) = K_p [e(n) - e(n-1)] + K_i e(n) + K_D [e(n) - 2e(n-1) + e(n-2)] \quad (4)$$

In formula 2, K_p is the proportionality coefficient, K_i is the integral coefficient, K_D is the differential coefficient.

$$K_i = K_p \frac{T}{T_i} \quad (5)$$

$$K_D = K_p \frac{T_D}{T} \quad (6)$$

3.2. Program implementation

The programming software CCS3.3, specially designed for DSP development by TI company, is programmed. The mathematical basis of the program is formula 4. The PID control procedure is as follows:

LT	EK	; $T = e_{k-1}$
MPY	K2	; $P = e_{k-1} \times K_2$
LACC	GIVE	; A given value
SUB	MEASURE	; Less feedback
SACL	EK	; Save the deviation e_k
LACC	UK,12	; u_{k-1}
LTA	EK	; $ACC = u_{k-1} + e_{k-1} \times K_2$
MPY	K1	; $P = e_k \times K_1$
APAC		; $ACC = u_{k-1} + e_{k-1} \times K_2 + e_k \times K_1$
SCAH	UK,4	; preservation

4. Servo motor tracking control experiment

The literature ^[1] pointed out that the output value of the speed measuring motor controlled by MCU in the process of the rough homing tracking was up to about 12V, when gradually failed to keep up with the speed of the gyro motor. Figure 6 shows the output voltage of the speed measuring motor when pendulous gyroscope for erection of east 90 degrees, displayed by OWON oscilloscope. The figure shows that a-b section for coarse search north phase, servo motor tracking gyro motor is normal, and in the b-c section, began gradually tracking backward. Stipulated east is negative, the b-c section speed measuring motor output changed from around -12 v to about 7 v. It can be seen that the control servo platform will reach the tracking limit when the speed measuring motor output is about 12V.

When the prototype used DSP as the control core, the dc servo motor is controlled by the incremental PID algorithm. Also put prototype for erection of east 90 degrees, the speed motor output as shown in figure7, the change of a-b section is not obvious, while b-c section changed a lot, speed measuring motor output can reach about 14.5 V. The new control scheme is proved to be effective.



Figure 6. MCU control speed motor output

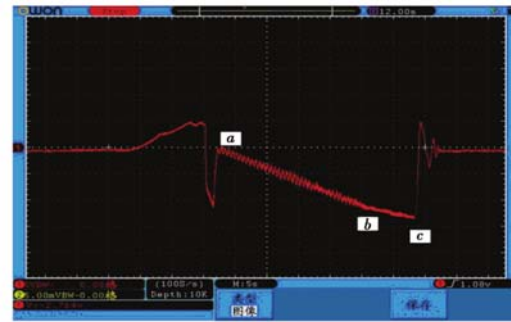


Figure 7. DSP control speed motor output

5. Conclusion

In order to solve the prototype at the time of initial deviation Angle is greater than 40 degrees, servo motor can not track the gyro motor, this paper used DSP28027 as the core control component and the incremental digital PID algorithm, designed the control circuit of the servo platform of pendulous gyroscope. The experiment proves that the scheme can improve the tracking performance of the servo platform, and it is beneficial to improve the performance of the prototype.

Acknowledgments

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