CONTROL OF ULTRASONIC MOTOR BASED ON DSP

Xiaojun Huang and Mingli Yu
Nanjing University of Aeronautics and Astronautics, Nanjing, P. R. China

ABSTRACT

Considering the special working principle of USM (ultrasonic motor), we selected a drive voltage which was taken as the controlling variable to regulate its speed. In this paper, we improved the traditional PID control into incremental PID control. In order to realize the speed control of USM, a controller based on DSP2812 was designed. Applying sine signals of different frequencies through the experiment, we'll find that the developed control scheme was highly effective, reliable and applicable for the ultrasonic motor.

KEYWORDS: *DSP, PID, ultrasonic motor.*

I. INTRODUCTION

The USM is a new type motor which has many excellent performance features such as high torque at low speed, silence, compactness in size and so on. It has different construction, characteristics [1] and operating principles than the commonly used conventional electromagnetic motors. The USM is driven by the mechanical vibration force of a piezoelectric ceramic in the stator, so the USM does not generate nor is affected by magnetic fields. In recent years, there have been many theories and methods reported for the control of USM. Some drive circuit for USM driving [2-8] has been set up. Most of these drive circuit was made up by some discrete components, including digital components, the simulation components, single-chip microcomputer and so on. The mixed-signal circuit needs to use a large number of discrete components. It will not be conducive to the stability, real-time and accuracy of the USM control.

In view of this, we set up a frequency, phase and duty cycle can be digitally controlled system which took the TMS320F2812DSP chip of TI company as the center. Together with multiple sets of constant voltage dc power supply formed the USM driving and control circuit. So we set up a hardware platform of control system which was simple and high real-time. Conduct the experiment with this system, the result is good.

II. WORKING PRINCIPLE OF THE CONTROL SYSTEM

The control system determines the quality of the whole experiment, so it is very important in the experiment. It is similar to the human brain，which receives the external information and issues instructions through its own processing and judgment to drive each component to complete the task. The main elements of the experiment system are: a computer, the software system, sensors, source voltage, the USM and its drive system. The relationship between these elements was shown in figure

1. Giving a signal by the computer, the control system drives the motor operating. The sensor will send the angle signal of the USM to DSP. Afterwards, the angle of the USM will be corrected by the control system according to the feedback signal of the sensor. So, the tracking control is realized.

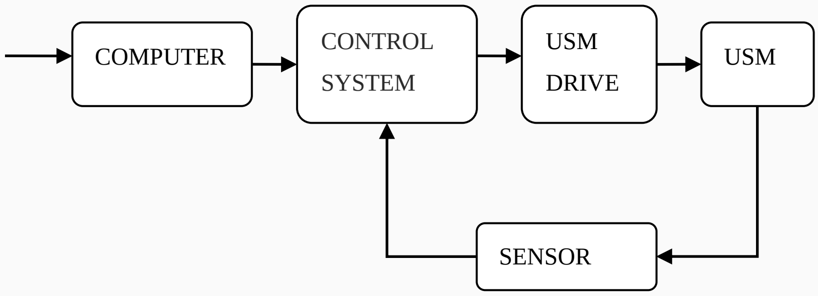

Fig . 1 Elements of the control system

III. THE HARDWARE PLATFORM OF THE SYSTEM

3.1 The choice of the USM

The USM used in this experiment was 40DDSO which was independently developed by Nanjing University of Aeronautics and Astronautics. Its main parameters: the weight is 64g, the rated torque is 0.15 Nm and the maximum speed is 260 rpm.

3.2 The choice of the sensor

Due to the precision and voltage requirements, we chose the NEMICON OVW2-1024-2MD coder which was made in Japan as the sensor. It has $1024 * 4 = 4096$ count pulses every circle. So its resolution is: $360^\circ / 4096 = 0.08789062^\circ$.

3.3 The choice of source voltage

Source voltage was necessary to be solved in this experiment. DSP, USM, coder all require power. To reduce the complexity of the system, we focused on major energy-consuming components of the control system. The main components and the voltage they require are shown in table 1.

Table 1 The main components and the voltage they required

COMPONENT	DSP2812M	USM			Coder
		Working voltage	Start-stop, Positive and negative rotation	Speed control	
voltage (V)	+5V	+12V	+5V	0~+5V	+5V

By table 1, we decided that the start-stop, positive &negative rotation and speed control were all supplied by DA of DSP, and the coder was connected to the QEP of DSP. In addition we also needed a *+12 v* and *+5 v* source voltage for the USM and DSP. The experimental setup was given in figure 2.

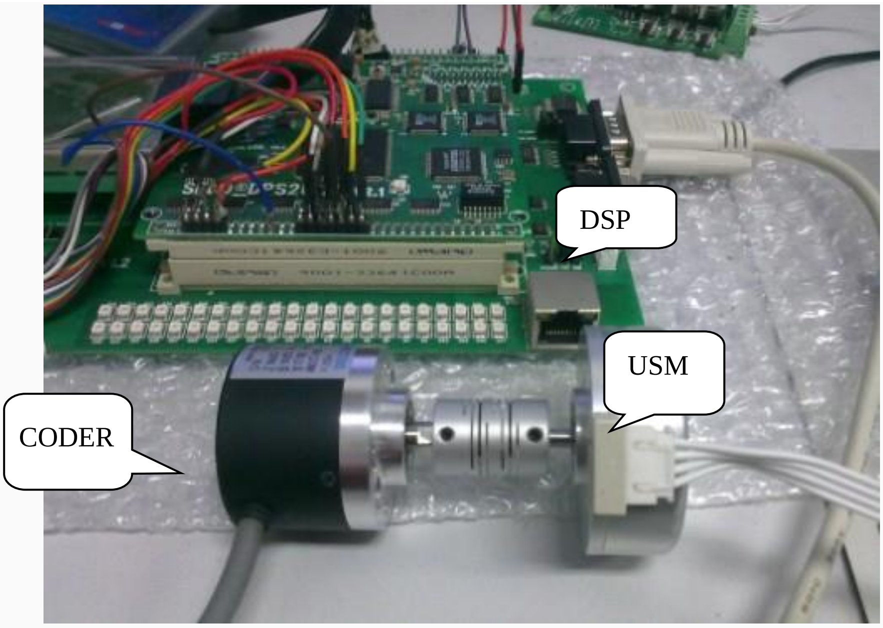

Fig . 2 The experimental setup

IV. The Control Method and Software Implementation

We used the incremental PID as the control method in the experiment. The traditional PID control was expressed as equation (1).

$$u(t) = K_P[e(t) + \frac{1}{T_i}\int_0^t e(t)dt + T_d \frac{de(t)}{dt}] \quad (1)$$

Where *u(t)* is the control signal acting on the error signal *e(t)*, *Kp* is the proportional gain, *Ti* and *Td* are integral time constant and derivative time constant, respectively.

Making equation (1) discrete, which uses sum instead of integral and the difference instead of differential, then we will get a digital PID control as equation (2).

$$u(k) = K_P e(k) + K_I \sum_{i=0}^{k} e_i + K_D[e(k) - e(k-1)] \quad (2)$$

There is a cumulative part *Σei* in formula 2, so, along with the increasing of k, the *Σei* will also increase. It will increase the difficulty of the algorithm and the complexity of the software system. Considering above reasons, the PID algorithm is needed to be improved. We can calculate *u(k-1)* as equation 3 .

$$u(k-1) = K_P e(k-1) + K_I \sum_{i=0}^{k-1} e_i + K_D[e(k-1) - e(k-2)] \quad (3)$$

Formula 2 minus formula 3, we'll get formula 4 .

$$\begin{aligned} \Delta u(k) &= u(k) - u(k-1) \\ &= K_P[e(k) - e(k-1)] + K_I e(k) + K_D[e(k) - 2e(k-1) + e(k-2)] \end{aligned} \quad (4)$$

Now the control algorithm has been simplified and formula 4 is called incremental PID[9-10] which will be used as a program algorithm to realize control . The flow chart of the program is shown in figure 3.

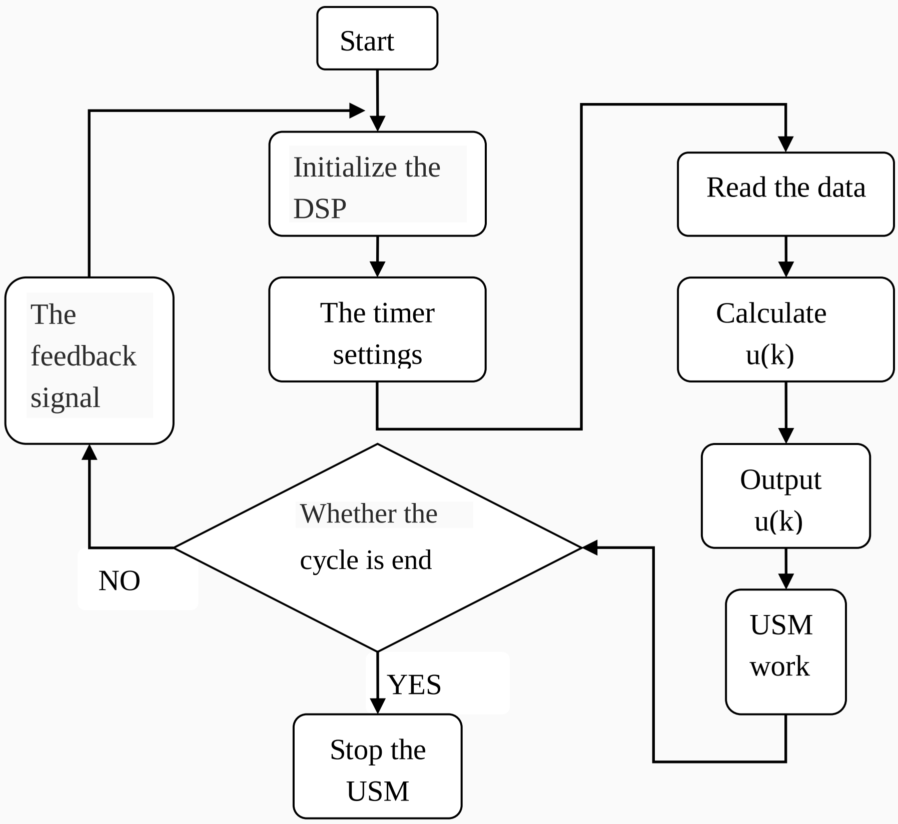

Fig . 3 Flow chart of the program

V. ANALYSIS OF THE EXPERIMENTAL RESULTS

After debugging the program successfully, we'll drive the USM through sine signals of different frequencies. We list several pictures of some sine signals with different frequencies in Fig 4. Results show that, when the frequency is low, the USM tracks ideally. With the increasing of the frequency, the amplitude and phase difference between the tracking signal and the original signal is larger and larger. When the frequency is 15Hz, the USM can't track the original signal.

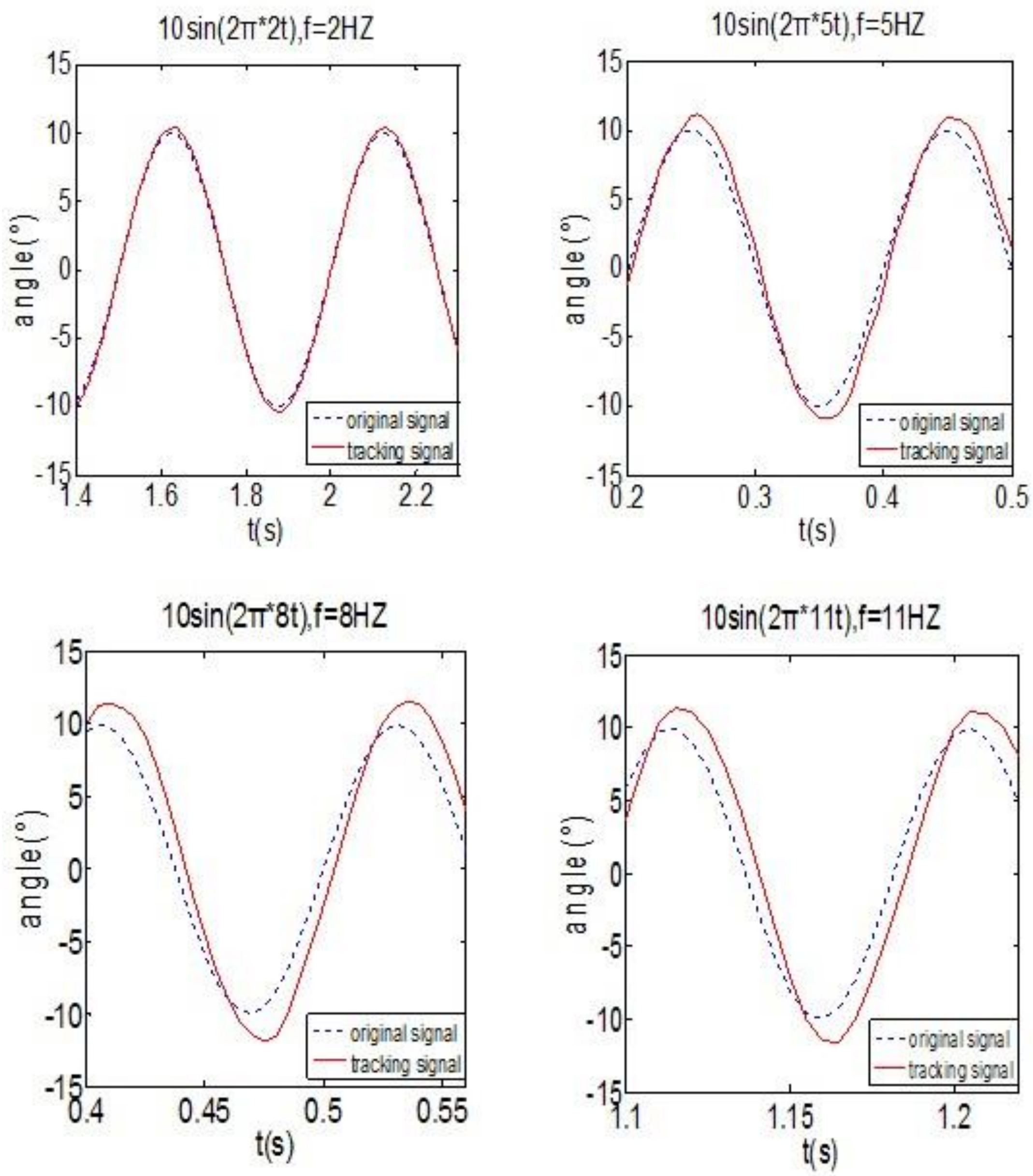

Fig.4 Control effect of different frequencies

VI. Conclusion

In this paper, a highly effective controller for a USM was implemented. A incremental PID controller was designed to provide effective tracking performance of the USM. This control was achieved by a TMS320F2812 DSP. Through the experiment, we can find out that the drive circuit of the control system run stably, the system is simple. We achieved the expected control effect. In the future I will try to use other control methods and compare their control effects to choose a better one. It's significant for the USM control.

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AUTHOR

Xiaojun Huang was born in Jiangsu province, China, in 1987. He received the Bachelor degree from the University of Hohai, Changzhou, in 2010. He is currently pursuing the Master degree with the Department of Mechanical Engineering, Nanjing. His research interests include program design and motor control.