Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(2):205-209

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

High accuracy speed measurement for rotary motor based on DSP

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ABSTRACT

Measurement of the motor speed has great influence on the control effect of effectiveness and precision of motor control. Conventional methods such as M method, T method, M/T method cannot satisfy the demand of the velocity measurement error in the operating range of the motor. A new method for speed measurement based on Digital signal processor TMS320x28xxx is presented; the experiments show that the new method can meet the accuracy requirements in the operating range of the motor.

Key words: Speed measurement; error analysis; Digital signal processor

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INTRODUCTION

Now the electric vehicle regularly use motor as the driven system, and asynchronous motor is widely applied in electric car because of its low cost, durable, easy maintenance, reliability, large output torque, high speed[1-2]. It is very important to control the motor to meet the speed performance requirements. Therefore, motor speed control system designed for electric vehicle performance is significant [3-4].

In the induction motor drive system, in order to meet the requirements of high-performance control, closed-loop speed control is needed, so the induction motor speed is required. In high-performance induction motor speed control system, the accuracy of speed measurement makes great impact on the performance of motor speed control system [5].

Commonly used methods based on the motor speed optical encoder are the following: M- method, T- method, M / T method, variable M / T method. In this paper, a comparative analysis of the various methods commonly used method for speed is presented, and the suitable method is implemented on DSP speed measure module is designed and implemented.

ANALYSIS OF TRADITIONAL SPEED MEASUREMENTS METHODS

The traditional speed measurements are measuring frequency speed method (M method), measuring time speed method (T method) and measuring both frequency and time speed method (M/T method).

In the M method, the pulse of photoelectric encoder by the fixed interval is counted and the average speed is got. The calculation is [6]:

$$n_M = 60\frac{m_1}{PT_S} \tag{1}$$

where n_M is the speed measurement and unit is rpm; m_1 is the count of pulse in the period T_S, P is the output pulses per cycle of the photoelectric encoder.

The speed resolution of the M method is:

$$Q = 60\frac{m_1 + 1}{PT_S} - 60\frac{m_1}{PT_S} = 60\frac{1}{PT_S} \quad (2)$$

From (2) it can be known that the speed resolution of the M method is related with P and T_S, the count of pulse m_1 has no effect on the speed resolution. The speed resolution becomes large when the value of P and T_S is large, and although the detection time T_S is constant, the start time of the detection time is random, so ±1 one optical pulse could happened during the measurement procedure, and the relative error is $\frac{1}{m_1}$, so the M method is suitable for high speed measurement[7].

In the T method, there is the high frequency clock pulse within an unit pulse interval of the encoder. By counting the pulses , the speed is obtained：

$$n_T = 60\frac{f_c}{Pm_2} \quad (3)$$

where n_T is the speed measurement and unit is rpm; f_c is the frequency of the clock pulse; m_2 is the count of f_c pulse; P is the output pulses per cycle of the photoelectric encoder.

The speed resolution of the T method is:

$$Q = 60\frac{f_c}{Pm_2} - 60\frac{f_c}{P(m_S + 1)} = \frac{n_M^2 P}{60 f_c + n_M P} \quad (4)$$

From (4) it can be known that the speed resolution of the T method is related with n_M and the relationship is nonlinear. As the start time of the detection time is random, so ±1 one optical pulse could happened during the measurement procedure, so the T method is suitable for low speed measurement.

In the M/T method, both the of detection time and the number of pulses of the photoelectric encoder detected within this time are used to obtain the speed[8]:

$$n_{M/T} = 60\frac{f_c m_1}{Pm_2} \quad (5)$$

where $n_{M/T}$ is the speed measurement and unit is rpm; $60\frac{f_c}{P}$ is the constant; m_1 is the count of photoelectric encoder; m_2 is the count of detection time clock pulse[9].

Principle of M / T method is shown in Fig1:

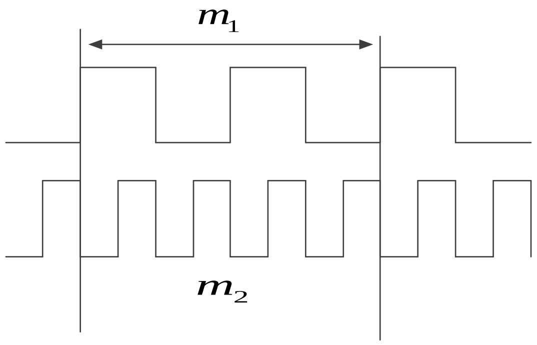

Fig. 1: principle of M / T method

The speed resolution of the M/T method is:

$$Q = 60\frac{f_c m_1}{P}\left(\frac{1}{m_2 - 1} - \frac{1}{m_2}\right) = \frac{60 f_c m_1}{P m_2 (m_2 - 1)} = \frac{n_{M/T}}{m_2 - 1} \qquad (6)$$

From (6) it can be known that the as the $Q / n_{M/T}$ is constant, the M/T method has no relationship with speed and it works in both high speed situation and low speed situation. So the M/T method is better than the M method and T method [10].

To widen the speed measurement range of the motor, it is needed to adopt the M/T method. Since the realizations of the M/T method are various, its realization is designed by the software based on DSP's hardware itself, without additional hardware.

THE ENHANCED QUADRATURE ENCODER PULSE MODULE OF DIGITAL SIGNAL PROCESSOR TMS320X28XXX

The enhanced quadrature encoder pulse (eQEP) module of DSP is used for direct interface with a linear or rotary incremental encoder to get position, direction, and speed information from a rotating machine for use in a high-performance motion and position-control system.

The eQEP module mainly includes Quadrature decoder unit (QDU), Position counter and control unit for position measurement (PCCU), Quadrature edge-capture unit for low-speed measurement (QCAP), Unit time base for speed/frequency measurement (UTIME), Watchdog timer for detecting stalls (QWDOG).The Quadrature decoder unit is used to choose the operation mode of the eQEP module. Position counter and control unit for position measurement is used to count the pluses and decide when to reset the position counter. The eQEP peripheral includes an integrated edge capture unit to measure the elapsed time between the unit position events and the feature is typically used for low speed measurement.

The eQEP module can be used to realize M/T method. The speed period is decided by setting QUPRD of the QEP module, which is to create the UTOUT event and interrupt. The measuring pulse (QCLK) in the period is counted by the QEP's position counter (QPOSCNT). The UPEVNT is set to the same frequency with QCLK and the timer QCTMR is to be a synchronous timer of QCLK. In addition, interrupting is needed for the overflow of the timer and position setting of position counter. Thus, the formula (5)can be used for the designed M/T method.

EXPERIMENTAL VERIFICATION AND ANALYSIS

The experimental platform includes an AC motor and a dynamometer which is used to measure the speed of the motor and the measured value is used as standard speed. The interrupt period of eQEPmodule in DSP is 100us,encoder lines are 3072, the measuring pulse (QCLK) is set to the system clock divided by 128(the system clock is 150MHz), in this way the minimum value of speed measured is 0.696(rpm). In the actual measurement, the speed of the collected is then handled by a first-order filter. The measurement curves of various methods in low speed and high speed is shown in Fig.2 and Fig.3.

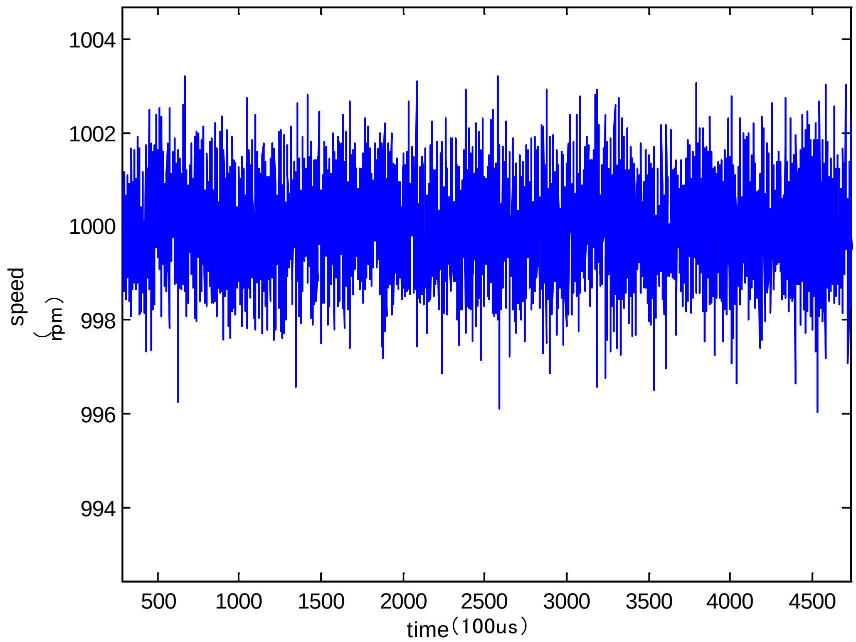

Fig.2: Measurement Curves of Various Methods in High speed

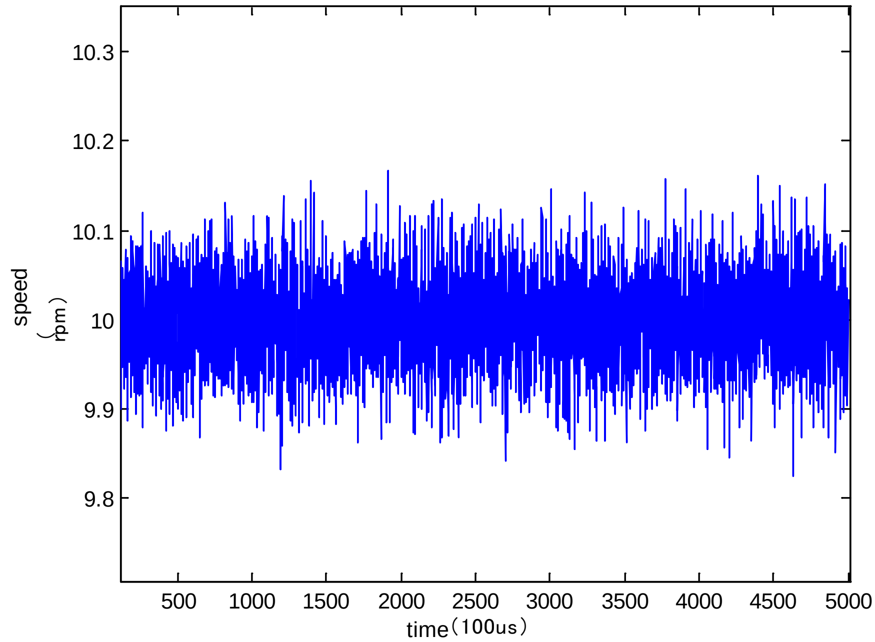

Fig.3: Measurement Curves of Various Methods in Low speed

CONCLUSION

In this paper, a comparative analysis of the various methods commonly used method for speed is presented, and the M / T method base on DSP speed measure module is designed and implemented, the experiment result show that the M/T method can keep enough measurement precision in low speed and high speed, and it can meet the accuracy requirements in the operating range of the motor.

Acknowledgments
The authors would like to thank Anhui Ankai Automobile Co., Ltd and National Electric Vehicle System Integration Engineering Research Center.

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