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Relay-style Digital Speed Measurement Method and Dynamic Position Subdivision Method

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ABSTRACT

This paper proposes an advanced M/T method called Relay-style Digital Speed Measurement Method. Its speed measurement is triggered by encoder pulse signals, which simplifies the complexity of processing incapability of synchronization in the classical method, and it makes actual sampling point always occur before the periodic sampling point in relay-style, which achieves the continuous dynamic iterative measurement with high accuracy in a wide speed range. Through counting the overflow pulses of time counter by software, the minimally measurable speed can be effectively extended to an extremely low level without adding any hardware. In addition, by utilizing the information in speed measurement and subdividing dynamic position by time according to its corresponding relationship with time, Dynamic Position Subdivision Method is achieved to improve the feedback resolution of dynamic position. Finally, the experimental results show that Relay-style Digital Speed Measurement Method can obtain high accuracy than classical method in a wide speed range even though at a very low speed Dynamic Position Subdivision Method is helpful to reduce the fluctuations of the position control.

1. Introduction

Speed and position measurement is a key aspect for AC servo systems which accuracy and bandwidth directly affect the systems control performance. Optical incremental encoders as an economical feedback component is an ideal solution to balance performance and cost, and widely used in AC servo systems for position and speed measurements [1–3]. Low level information is provided in the form of two orthogonal pulse trains that are transmitted to the control system which calculates actual position and speed needed for motor control, so the measurement method on the frequency and number of the encoder pulses plays an important role in modern servo systems.

Classical methods for pulse frequency measurements are M method, T method and M/T method. M method is directly counting pulses within a constant time; T method is realized by counting the number of a high frequency clock to detect the time inside one (or more) encoder pulse; and M/T method uses both pulse counting and time measurement, providing less measurement error than M method and T method. It can be analyzed that M method is well suited for high-speed application, while the contrary is true for T method and M/T method [4]. Some improved methods have been proposed in the recent past regarding the three frequency measurement methods. The availability of low-cost microprocessor with an integrated free running counter and “input capture” functionality, led to the development of pure software solutions [5,6]. By taking advantage of the microprocessor capture port to simultaneously sample the rising edge of encoder pulses, the method can achieve low cost with a simple hardware structure. The main shortcoming of this implementation is the limitation at a very high speed. Actually, the high frequency of interrupts generated by encoder pulses would affect the real-time performance of control software, and the measurement accuracy is limited by instruction cycles. In order to alleviate the burden of control software, VLSI chip is presented to obtain position and velocity measurements from optical incremental encoder feedbacks [7]. The sampling time width can be adjusted by an external window enable signal to improve the measurement flexibility, but the pulses without the window time that may affect the speed will be missed because the method is not continuous. With the FPGA technology development, its implementations of encoder-based speed measurements are reported. The Time-to-digital converter (TDC) module in FPGA device and high frequency clock are adopted to synchronize encoder pulse signals and observation window [8], so extremely low error level can be achieved in a wide speed range by adaptively changing sampling time intervals but the hardware complexity is increased. On the other hand, a relatively small (16-bits typically) time counter in FPGAs or VLSIs may overflow at a very low speed. For that

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reason, an ancillary time counter is used to resolve time elapsed in the two contiguous encoder pulses, while a pre-settable time counter is used to vary gate time in the chip, which brings high cost to system [9]. Except for the speed detection methods that are based on the direct measurement of the encoder signals frequency, several methods have been developed in order to obtain high precision position and speed detection which are commonly addressed as "observer methods" [10–14], for example Kalman Filter methods and Luenberger observer methods that are used to decrease the measure errors. However, these techniques usually require floating point computation and models of the system dynamics, and noise statistics [15]. Finally, the implementation efforts are subsequently suffered from the dependence on proper state models and their parameters that are difficult to be obtained in application.

Despite the wide variety of existing speed measurement methods, we are still facing following challenges:

(1) Reducing the number of control software real-time operations in measurement process.
(2) Accuracy synchronization between encoder pulse signals and observation window.
(3) Measurement bandwidth.
(4) Iterative measurement without missing encoder pulses.
(5) Realization of ultra-low speed measurement in an economical method.

On the aspect of position measurements, current dynamic position measurements only rely on the number of encoder pulses, and do not consider the time information in the encoder pulses as well as the corresponding relationship that dynamic position is integration of speed in time. So the resolution is limited by the encoder pulses per revolution, which is an obstacle to the servo control performance improvement.

Compared with previously published works, this paper presents the Relay-style Digital Speed Measurement (RDSM) method based on M/T method and the Dynamic Position Subdivision (DPS) method. Particularly, the propositional speed measurement method can measure speed iteratively without missing encoder pulses, and provides good measurement accuracy over a wide range without affecting the software real-time performance. With simple computation, ultra-low speed measurements in the low cost can be realized. In addition, DPS method, utilizing the speed information measured by RDSM method and time information in the encoder pulses, brings the higher resolution than classical dynamic position measurement methods, and thus achieves the improvement of servo performance.

This paper is organized as follows: the next section describes the measurement process with particular emphasis on how to overcome the above challenges, and analyzes the measurement performance and describes how to extend the low limit of speed measurement. Section 3 introduces Dynamic Position Subdivision Method. Section 4 presents and discusses the testing and experimental results, while Section 5 gives the final conclusions.

2. RDSM method and its performance analysis

2.1. RDSM method

Speed measurement function block diagram is presented in Fig. 1. This is a digital circuit, processing the pulses produced by the orthogonal incremental encoder and providing in its output the number of actual pulses and the number of corresponding high frequency clocks. The clean pulses multiplied by four and direction signals are obtained through a simple pulse technique (the bottom section of Fig. 1). The main function blocks are described as follows: Period Time Counter (T_p) is used to measure the encoder pulse width while Overflag (O_v) is the overflow indication of Period Time Counter, and Time Accumulator (T_a) contains total time clocks number that is the width of several encoder pulses measured. Pulse Counter is counting the encoder pulses number. The content of the Pulse Number Register (C_R) is then the number of encoder pulses measured, and the content of the Time Register (T_R) is the number of time clocks measured. Command Register is used to generate read/write signals for relative registers and sample signals to control the observation window width.

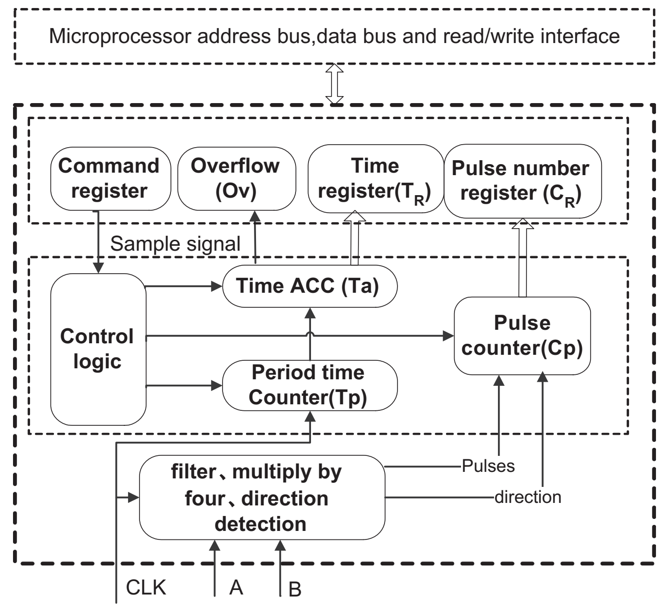

Fig. 1. Function block diagram of Relay-Style Digital Speed Measurement.

RDSM method process can be explained with the aid of the function block diagram of Fig. 1 and the timing diagram of Fig. 2. When the rising edge of the encoder pulse arrives (actual sampling point A in Fig. 2), Pulse Counter is cleared and Period Time Counter begins to count. Consequently, at every rising edge of the encoder pulses in the observation window time (T_s), Time Accumulator accumulates the content of Period Time Counter while Pulse Counter is increased by one, then Period Time Counter starts counting from zero immediately. When the rising edge of the periodic sample signal (point S in Fig. 2) is coming, the content of Pulse Counter and Time Accumulator is transferred to Pulse Number Register and Time Register respectively, then Pulse Counter and Time Accumulator are cleared immediately. The content of Pulse Number Register (C_R) is the number of encoder pulses measured, and the content of the Time Register (T_R) is the number of time clocks measured. The contents of C_R and T_R are used to calculate speed, because C_R contains the position difference and T_R holds the accurate sampling

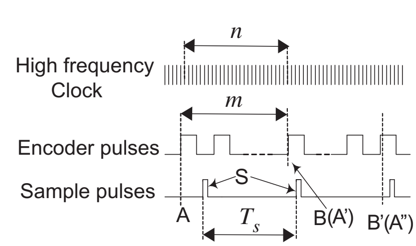

Fig. 2. Timing diagram of Relay-Style Digital Speed Measurement.