IncOder™ App Note

Calculating Speed

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1.0 Introduction

Zettlex IncOders are devices for accurate measurement of angle in demanding environments. IncOder applications such as radars, scanners, stabilized platforms and motor drives often require accurate and responsive (low latency) angular speed measurement. If such speed measurement alone is required, then the recommended solution is an IncOder with A/B pulse output. The aim of this note is to provide further technical background and information for design engineers using IncOders to measure absolute angle <u>and</u> calculate angular speed accurately with low latency.

IncOders with 0-10V analogue outputs are generally not recommended for angular speed measurement. Typically, angular speed measurement is required for continuously rotating applications and 0-10V electrical outputs are most suited to applications with a range of $\leq 360^{O}$.

The first option for absolute angle and angular speed measurement is to use a Duplex IncOder (referred to as INC-10 mechanical format); pairing an absolute digital output unit with an A/B pulse output unit in a single mechanical housing. Typically, the absolute digital output device is located on the outer ring for angle measurement and the A/B pulse output device is located on the inner ring for angular speed measurement. Such an approach gives high accuracy, absolute angle measurement with an independent, low latency angular speed measurement. This electrical independence can be beneficial or mandatory in some instances, however, using a duplex IncOder may be precluded in your application due to other design constraints such as cabling or physical size.

There are various other options for absolute angle and angular speed measurement using SSI, SPI or ASI and this second group of options is discussed in the following section:-

2. Speed Measurement with absolute, digital output IncOders

The IncOder range offers various absolute, digital outputs and they use a number of different communications protocols. These include various synchronous protocols (SPI1 and SSI1 to 8) and one asynchronous protocol (ASI1).

2.1 Synchronous Protocol SPI1

The SPI1 protocol employs a clock signal, provided by the host controller, which the IncOder uses as a signal to transmit its absolute angle data. It is possible to use this protocol to synchronise the IncOder measurements to the data transmissions (see the IncOder Product Guide for further details). In this mode, the controller can use its own timing information to calculate angular speed using the absolute angle data received from the IncOder.

2.2 Synchronous Protocol SSI1 through SSI8

These protocols also rely on the controller to provide a clock signal. Generally, they are not useful for *accurately* calculating speed, as the controller has no precise knowledge of when the IncOder has made the absolute angle measurement.

There is one exception and that is SSI4. The SSI4 protocol is designed specifically for *accurate* and low latency angular speed measurement. It transmits a time stamp, which records the time at which the measurement was made, and supplies this data along with the measured angle in its digital output. The controller can use this data to accurately calculate the angular speed.

<u>Typically, Zettlex recommends the use of SPI1 or SSI4 for accurate angle measurement and angular speed calculation.</u>

2.3 Asynchronous Protocol: ASI1

IncOders using the ASI1 protocol continuously transmit angle data, at a rate of between 1kHz and 1.25kHz. This fact can be used to calculate angular speed. If higher accuracy is required, then the controller can time the interval between received data packets and use this timing information in calculating angular speed.

2.4 Method

With all three IncOder types mentioned above (SPI1, SSI1-8 and ASI1), the method of calculation is the same, but the method of obtaining the timing data varies. Only the SSI4 IncOder supplies all the data required to calculate speed, whereas SPI1 and ASI1 rely on data that the controller must determine independently. The method below is for an SSI4 IncOder (where the resolution of the time stamp is known). For ASI1 and SPI1 IncOders, the time units will be dependent on the controller.

Once the timing information is available, calculating speed is simply a matter of taking the change in angle and dividing by the change in time:

$$Rate = \frac{\Delta\theta}{\Delta T} \tag{1}$$

To calculate speed in radians/sec, the data in the above equation should be converted to the appropriate units.

The units for angle depend on the resolution of the IncOder. The change in angle in radians can be calculated as:

$$\Delta\theta = \frac{2 \times \pi \times (P_n - P_{n-1})}{2^R} \tag{2}$$

R is the resolution of the IncOder in bits.
P is the angle data from the IncOder.
n represents the current data, and *n-1* represents the previous data.

For SSI4 IncOders, the time stamp has a single bit resolution of 10µs. So the time period between measurements in seconds is calculated as:

$$\Delta T = \frac{(T_n - T_{n-1})}{10^5} \tag{3}$$

T is the time stamp from the IncOder.

n represents the current data, and *n-1* represents the previous data.

So substituting equations (2) and (3) into (1), the speed in radians/sec is:

$$Rate = \frac{\Delta\theta}{\Delta T} = \frac{2 \times \pi \times (P_n - P_{n-1})}{2^R} \times \frac{10^5}{(T_n - T_{n-1})}$$

As the angle and time stamp data have finite ranges, these values will at some time reset to zero. This must be accounted for when calculating ΔT and $\Delta\theta$.

For the timestamp in SSI4, the range is 20.46ms. For angle, the range is dependent on the IncOder resolution (*R*), and is calculated as $2^R - 1$. Note that angle can transition from $2^R - 1$ to zero and vice-versa depending on the direction of rotation.

If you require further information please contact Zettlex or your local Zettlex representative.

3. Change Record

Revision	Notes	By	Date
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