In high performance digital motor control system with wide speed control range, certain IC's are still required to through which to get the motor feedback position or speed signals. There are many types of sensors, such as tachometer, potentiometers, resolvers, and optical encoders, for getting the motor rotation angle or speed. Among them, the optical encoder is the most commonly used because it output signal is digital with high noise immunity and high resolution.

The Required Functions

Fig. 2. Shows the system function block diagram of the Interface IC, which has an two-phase interface to an optical encoder and an 8-bit interface to a standard microprocessor or application specific digital system.

Since many motors are usually working in noisy environments, which might introduce unwanted noise in the encoder’s output due to electromagnetic coupling or vibration. A pair of digital filters is used for Channel A and Channel B to filter out the noise on the incoming signals. A quadrature decoder circuit is also needed to decode the incoming filtered signals for determining the motor rotation direction and multiply the resolution of incoming signal by a factor of four. A position counter is then needed to up or down count the resulting decoded pulse according to the rotation direction indication from one of the decoder outputs.
Design of the Interface IC

Digital Filter
The design of digital filter is based on the finite state machine model and datapath (FSMD). Fig. 3 shows the architecture of the digital filter that consists of a control unit and a datapath on each channel. The control unit is a recognizer that checks if the input from the optical encoder has short duration pulses, and controls the input data to flow through the datapath, which consists of 2:1 multiplexer and a D flip-flop. If the input level has the same value (1 or 0) on at least three consecutive clock cycles, the input is not considered as noise. In this case the output of the recognizer is active high, which then allows the input data to flow through the datapath. The data has thus become the new output of the filter. Otherwise the input is considered as noise and the datapath output of filter remains the same.

Quadrature Decoder
The Quadrature decoder section consists of a direction decoder and a 4-time rate circuit. It samples the two quadrature signals from the digital filter's outputs and observes changes in these outputs on the rising clock edge. The two Quadrature signals can be encoded as four states. The state changes can be detected by comparing the previous sampled data with the current sampled state. This can in turn multiply the input signal frequency by a factor of four.

A new method for detecting the rotation direction of motion is shown in Fig. 5. It can be seen that the encoded state of 8, 14, 7 and 1 in the clockwise direction are different from those states of 2, 11, 13 and 4. Thus we can use 4-to-16 demultiplexer and some output logic to detect the direction. The count direction is also determined by observing the previous and current states. The designed circuit is shown in Fig. 6.
Methods to Increase the Resolution of Optical Encoders in Motion Servo Systems

Most high performance motion control systems rely on optical encoders for position and velocity feedback. The optical encoder is the essential feedback element on the servo loop. For a higher precision servo system, the feedback signal requires a higher resolution. One way to increase the resolution of optical encoder without the need to increase its optical resolution is to use an interpolation method.

Most industrial encoders output sine-cosine current waveforms (A-B signals) as position information. This signal is then fed to Quadrature decoder circuit that gives up/down count pulses.

Quadrature decoding is the most common method to decode the phase A-B signals into up/down count pulses. This has the advantages of simplicity and full digital implementation. However, the count pulse resolution is limited to four times its optical resolution. To increase the resolution of optical encoders more than fourfold, a form of sine-cosine interpolation method has to be employed. Through interpolation, intermediate values of sine cosine waveforms can be found, and, through the detection of these intermediate values, much higher resolution of count pulses output can be achieved. Fig. 8 shows the interpolation of the sine cosine waveform to achieve a 16-fold resolution increase.

Presently, there are 3 commonly used methods to increase the resolution of optical encoders:

1. Use a resistor network to detect the magnitude of the sine cosine waveforms
2. Use ADC converters to acquire the current magnitudes of the sine cosine waveforms
3. Use of method similar to 2, but includes a variable resolution scheme to allow faster processing and access.

Method 1. The first method is to use analogue comparators to obtain the angle of the magnitude of the phase A and B signals. Since the output of the two signals from the optical encoder has a sine cosine relation, there is a one-to-one mapping of these signals to the intermediate position values of the optical encoder. This method has an advantage of straightforward circuit, with no software programming. However, it has some disadvantages:

I. Difficult to construct a precise resistor network
II. A large number of comparators are needed

III. Resolution decreases at higher speed

Method 2. This is the most common interpolation method used in motion control system. Rather than building a large resistor network with a large number of comparators, the interpolation process can be implemented by a high speed data acquisition circuit. Fig. 9 shows the block diagram of such a data acquisition system. Such an approach has the advantage of high flexibility and large resolution increase. In some cases, resolution increase of up to x1024 can be achieved. However it has some disadvantages:

I. Complex circuit and expensive components cost due the ADCs and computing units
II. Only suitable for low speed operation, due to speed limitation of the processing unit and the data acquisition circuit.

The higher the resolution, the higher will be the pulse output rate, and higher will be the computing requirement. It is very expensive to implement a high speed and high-resolution interpolation decoder.

![Block Diagram of processor based interpolation unit](image)

Method 3. For most application, high resolution is not required for the high-speed motions, but when the system speed is very low or coming to a stop, high resolution is required. A typical application illustrating this is a automatic Drilling machine. In Drilling machine if the distance between the two points is large than the motor can run at high speed to reach the other point at low resolution, and as it approaches the other point it slows down the speed and hence can increase the resolution to accurately reach the destination point. The previous method has the advantage of high resolution, but it cannot travel at very high speed. To overcome this problem, many systems use a variable resolution scheme. When the speed is too fast for the computing unit to handle, its resolution decreases to reduce the computing burden. However this method has the disadvantages of complex hardware (to accommodate the flexible resolution scheme) and the problem of a "glitch" during resolution change.