Designing Encoder Elements for Two Channel Optical Interrupters

Application Bulletin 229

GENERAL DISCUSSION

Rotational direction of a shaft can be readily determined by utilizing the two channels of a dual optical interrupter, an encoder disc with a number of openings around the circumference, and some simple electronics. The speed and relative shaft location information is available as a by-product and requires some additional electronics.

Figure 1 is a pictorial definition of terms used in this bulletin and should be referred to for clarification. A period is defined as a fraction of 360 electrical degrees or the mechanical width of one opening plus one closure at the central point of the slot near the circumference of the encoder disc. In shaft encoding terminology, quadrature is the term defining the ability to determine the direction of movement by the phase relationship between the outputs of two channels. System design normally uses 90° for this phase shift. Speed can be determined by accumulating the number of signal pulses for a fixed period of time, dividing by the number of periods per revolution thus obtaining the revolutions for this time period. Relative location is determined by dividing 360 by the number of periods around the circumference. A pulse is generated for each of these rotational periods. Counters may be used to count the periods or to count the quadrature transitions (4 per period). This bulletin will describe the method of obtaining the information (rotation direction, speed, and relative location) rather than what is done with the information.

PERFORMANCE CHARACTERISTICS

First we should determine the number of periods on the disc. This can be an arbitrary number or referenced to the resolution of the steps on the disc. As an example: if 0.7° steps are required, you would count the 4 quadrature transitions per period, the number of periods per revolution would be 128 (Periods = 360° / [Degrees per transition * number of transitions] = 360/[128*4]). We will next calculate the period size, opening and closure width, centerline pitch radius, slot length and overall disc radius. The logical sequence for different off-multiples showing quadrature transitions will be covered last.

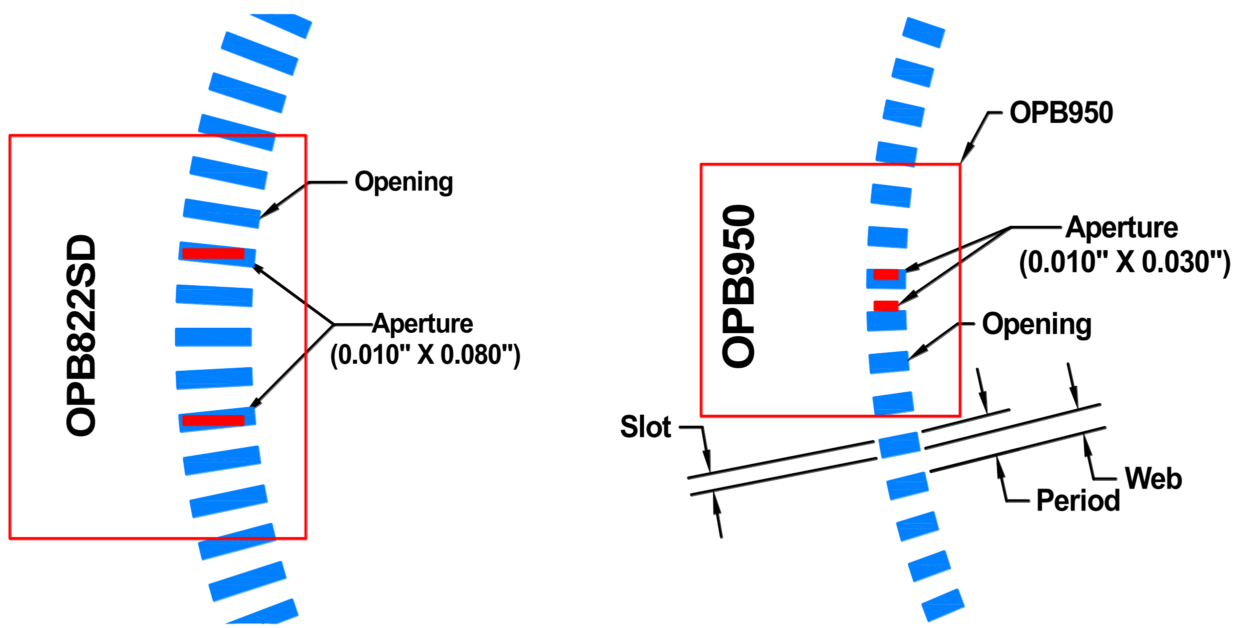

Figure 1:
Example of Period Width encoder wheel slots referenced to the OPB950 & OPB822SD Dual Channel Encoder

TT Electronics | Optek Technology
1645 Wallace Drive, Suite 130, Carrollton, TX, USA 75006 |Ph: +1 972-323-2300
www.ttelectronics.com | sensors@ttelectronics.com

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An off-multiple of periods between the center line of the sensor apertures is required for the 90° phase shift. The off-multiple can be 1/4, 3/4, 1-1/4, 1-3/4, 2-1/4, etc. periods. The Period Width is calculated by taking the Spacing between centerlines of the sensor divided by the off-multiple (Period Width = Distance between Aperture Centers / Off-Multiple).

Period Width = (Distance between Aperture Centers / Off-Multiple)

Example:
(0.212" / 4.25) = 0.050 (Reference OPB822SD)
(0.212" / 0.75) = 0.283 (Reference OPB822SD)
(0.040" / 1.25) = 0.032 (Reference OPB950)
(0.040" / 0.75) = 0.053 (Reference OPB950)

The opening in the disc should be greater than the width of the aperture (0.010" for both the OPB822SD and OPB950) otherwise this would decrease the guaranteed output signal. The period width will be divided into an opening for the light (slot) as well as an area for closure (web), blocking the light. In order to have a 50% duty cycle, large Period Widths can be separated into two equal sections while small Period Widths may require the slot to be smaller then the web.

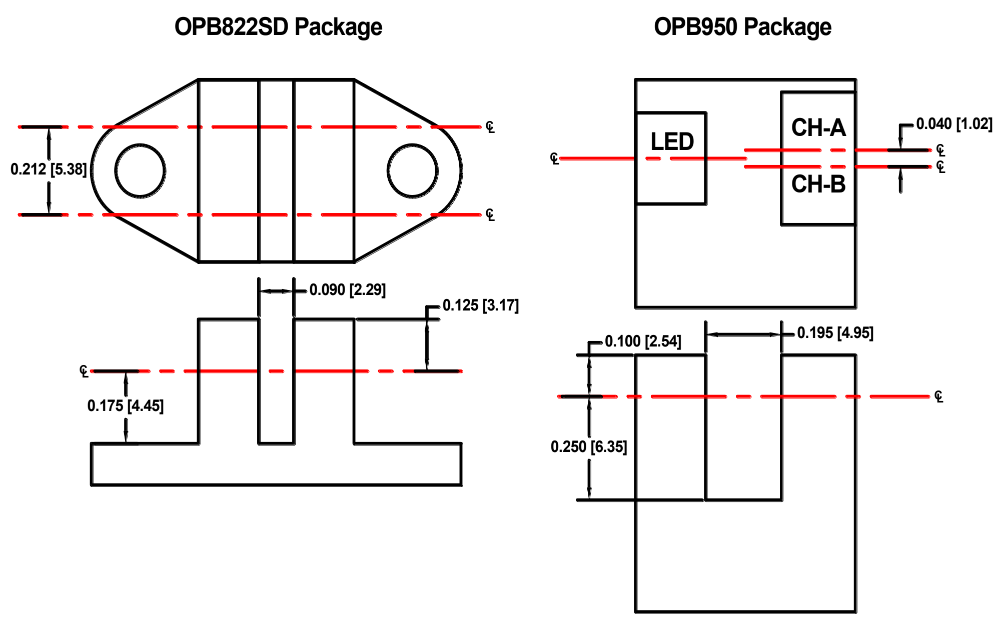
For a small Period Width with respect to the device aperture size, the aperture width should be taken into consideration. The opening (slot) width for the Period Width is calculated by taking 50% of the Period Width and subtracting 50% of the device aperture width (Opening Width = [0.5 * Period Width] - [0.5 * Aperture Width]). The closure (web) width is calculated by taking the Period Width and subtracting the Opening Width (Slot Width = Period Width - Web Width).

Slot Width = ([0.5 * Period Width] - [0.5 * Aperture Width])

Example:
([0.5 * 0.050"] - [0.5 * 0.010"]) = 0.020" (Reference OPB822SD)
([0.5 * 0.283"] - [0.5 * 0.010"]) = 0.137" (Reference OPB822SD)
([0.5 * 0.032"] - [0.5 * 0.010"]) = 0.011" (Reference OPB950)
([0.5 * 0.053"] - [0.5 * 0.010"]) = 0.022" (Reference OPB950)

Web Width = (Period Width - Opening Width)

Example:
(0.050" - 0.020") = 0.030" (Reference OPB822SD)
(0.283" - 0.137") = 0.146" (Reference OPB822SD)
(0.032" - 0.011") = 0.021" (Reference OPB950)
(0.053" - 0.021") = 0.031" (Reference OPB950)



The Centerline Pitch Radius, or the optical centerline of the slots, of the encoder disc is determined by multiplying the Period Width times the number of Periods per Revolution and divided by two times Pi (Pitch Radius = [Period Width X Periods per Revolution] / [2π]).

Centerline Pitch Radius = ([Period Width X Periods per Revolution] / 2π)

Example: ([0.050" * 128] / 6.283) = 1.016" (Reference OPB822SD)
([0.283" * 32] / 6.283) = 1.440" (Reference OPB822SD)
([0.032" * 128] / 6.283) = 0.652" (Reference OPB950)
([0.053" * 128] / 6.283) = 1.087" (Reference OPB950)

The slot length should be larger than the sensor aperture opening length. As a good rule of thumb, you can use 2 times the disc eccentricity of the wheel plus the sensor aperture length. While the maximum slot length would depend on the mechanical design of the disk. Remember the slot should totally fit inside housing of the encoder.

Minimum Slot Length =
(Aperture Length + [2 * Eccentricity]) (assume 0.010" eccentricity for these calculations)

Example: (0.080" + [2 * 0.010"]) = 0.100" (Reference OPB822SD)
(0.030" + [2 * 0.010"]) = 0.050" (Reference OPB950)

Disc material and thickness will vary depending on the application. The minimum width is determined by the material stiffness, opacity to near Infrared, and eccentricity expected. The maximum width is determined by the width of the slot and eccentricity expected.

The minimum Disc Radius is equal to the Centerline Pitch Radius plus one half the minimum slot length plus mechanically suitable support distance. The Maximum Disc Radius should take Centerline Pitch Radius plus Optical Centerline of the Aperture to the bottom of the encoder slot minus two times the Disc Eccentricity.

Minimum Disc Radius = (Centerline Pitch Radius + [0.5 * minimum slot length] + support distance

Example: (1.016" + [0.5 * 0.100"] + X" = 1.066" + X" (Reference OPB822SD)
(1.440" + [0.5 * 0.100"] + X" = 1.490" + X" (Reference OPB822SD)
(0.652" + [0.5 * .050"] + X" = 0.702" + X" (Reference OPB950)
(1.087" + [0.5 * .050"] + X" = 1.137" + X" (Reference OPB950)

Maximum Disc Radius = (Centerline Pitch Radius + Optical Center Line of aperture to Bottom of the encoder slot - [2 * Disc Eccentricity])

Example: (1.019" + 0.155" - [2 * 0.010"]) = 1.149" (Reference OPB822SD)
(1.441" + 0.155" - [2 * 0.010"]) = 1.571" (Reference OPB822SD)
(0.652" + 0.235 - [2 * 0.010"]) = 0.867" (Reference OPB950)
(1.080" + 0.235 - [2 * 0.010"]) = 1.295" (Reference OPB950)

The Disc should be made from a material that is compatible with the application. Types of material could be Plastic, Metal, or Glass with openings and or a pattern applied to it. The encoder wheel should have the pattern as close to the sensor side of the encoder as possible taking into account end play of the encoder.

The digital sequence expected from the each configuration is dependent on the position of the apertures of the device in reference to the slots in the encoder wheel. As can be seen, the sequence of where channel A and channel B cross the opening is dependent upon the off-multiple and the spacing of the channels.

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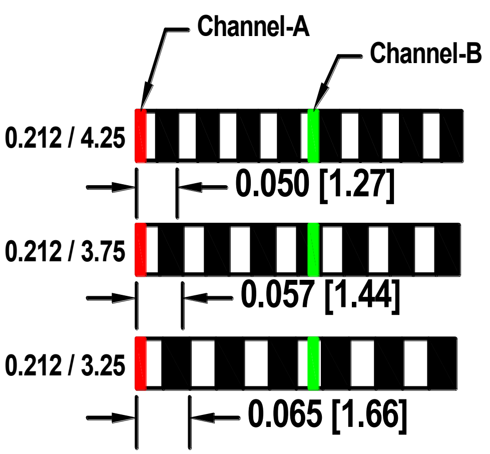
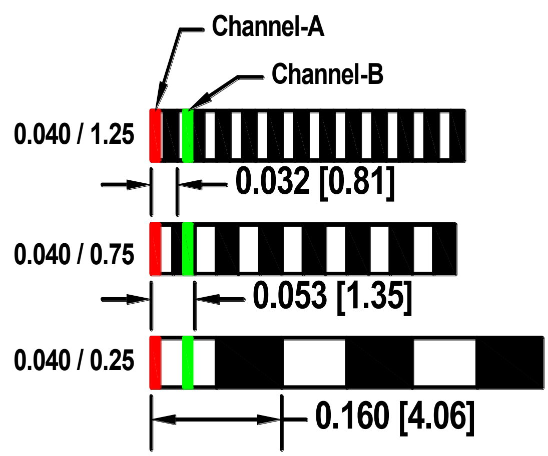
As the channel A of the OPB822SD is in an opening for the 0.212 / 4.25 configuration with the pulse width of 0.050", channel B is in the middle of an opening. On the other hand when channel A of the OPB950 is in an opening for the .040 / 0.75 configuration, channel B is in the middle of a closed part of the encoder wheel. This changes the logical sequence as seen below. By knowing the expected logical sequence, the direction as well as the speed of the wheel can be identified. As in the OPB822SD example the expected sequence is 1-1, 1-0, 0-0, 0-1 where the expected sequence for the OPB950 is 1-0, 1-1, 0-1, 0-0. As can be seen the 1-0 and 0-1 logical level sequences are reversed therefore you need to know the expected sequence to identify the direction of the encoder wheel. Off-multiples ending in ".25" will output a quadrature direction sequence opposite to the sequence with off-multiples ending in ".75".

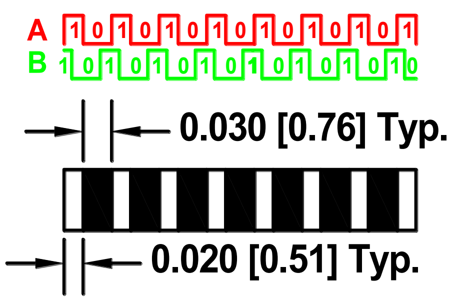
OPB822SD Spacing



OPB950 Spacing

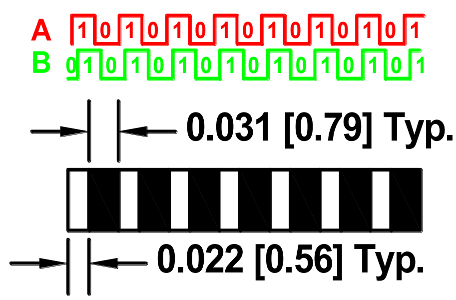


OPB822SD Spacing

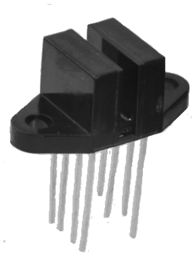


Example: Digital Pattern for OPB822SD with 0.050" Period Width

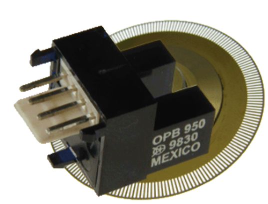
OPB950 Spacing



Example: Digital Pattern for OPB950 with 0.053" Period Width



OPB822SD



OPB950

TT Electronics | Optek Technology
1645 Wallace Drive, Suite 130, Carrollton, TX, USA 75006 |Ph: +1 972-323-2300
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