Application Note

Optical Encoding with HOA0901 and HOA0902 Series Optical Encoder Assemblies

OPTICAL ENCODER OVERVIEW

HOA0901 and HOA0902 Series Optical Encoders provide relative, incremental position and direction information, with a slot interrupter strip or disk. Some applications are:

- Computer mouse, joystick or trackball position and direction sensor
- Motor rotor position, speed and direction sensing
- Printer head position feedback sensing
- Control system valve or vane feedback position sensing

These devices are intended to operate with a continuous interrupter strip. The strip provides continuous indication of incremental motion.

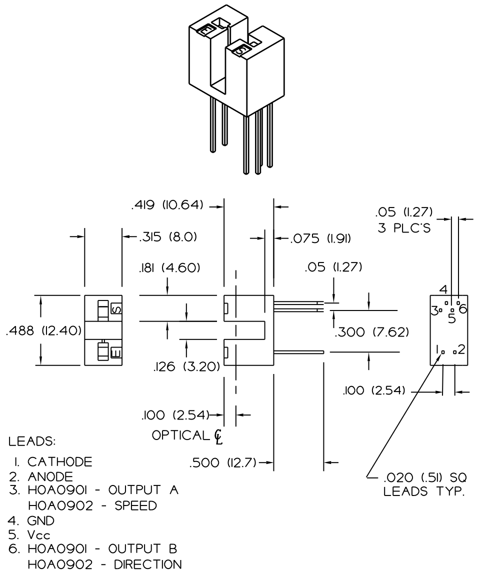
A slot interrupter is a series of slots in an opaque sheet of material, which is used to interrupt the light between the source and detector.

HOA0901 provides two channels of slot interrupter detection for use with custom decoders or microcomputers which perform the decoding function.

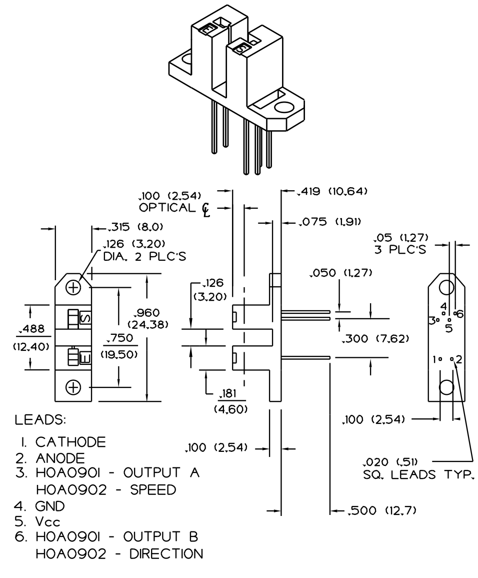
HOA0902 provides decoding specifically for direct slot count and slot motion direction indication.

This note is intended to help you choose the best encoder for your application, and to provide output decoding assistance.

HOA0901-11 and HOA0902-11 PCB mount assembly



HOA0901-12 and HOA0902-12 chassis mount assembly



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HOA0901 OPERATION

The block diagram in Figure 1 illustrates HOA0901 operation. Two identical optical receiver channels receive infrared light from a common LED source. Each channel converts the optical light impinging upon its detector into a logic output. A Schmitt trigger insures clean edges on output transitions. A third channel, which receives no light, acts as a reference to reject noise and improve detection level stability over voltage and temperature.

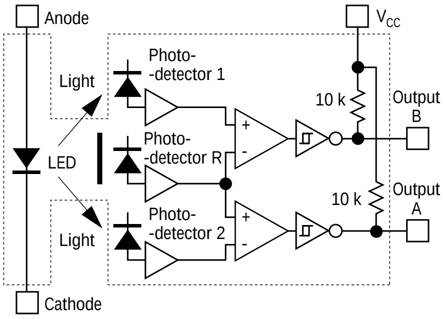
When the slot interrupter moves past the two photodetectors, the channels provide a regular on/off pattern versus position.

The A output leads the B output in time when the slot interrupter moves from right to left (seen from the top with S end facing up). With proper slot design (see DESIGNING SLOT INTERRUPTER), the A and B outputs can be set to operate in "quadrature" (90° relative phase shift in the outputs relative to slot interrupter position).

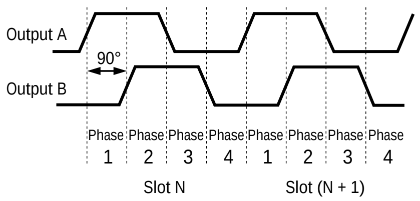
Note: output A leads output B if the slot interrupter movement is from A to B. B leads A for slot interrupter movement in the opposite direction. Thus, the quadrature outputs can detect direction of the slot interrupter motion.

Figure 1

a. HOA0901 functional block diagram



b. HOA0901 output switching diagram



HOA0902 OPERATION

The HOA0902 operates similarly to the HOA0901, except that the outputs are decoded versions of HOA0901 A and B signals (see Figure 2). Decoding provides DIRECTION and TACH signals. DIRECTION is a logic signal which is low when A leads B (left to right). TACH signal is a fixed duration pulse output occurring every time the A channel level changes. In contrast, HOA0901 provides A and B outputs separately for those building their own decoders.

HOA0901 VERSUS HOA0902

Your choice of HOA0901 or HOA0902 depends largely upon the function you want it to perform.

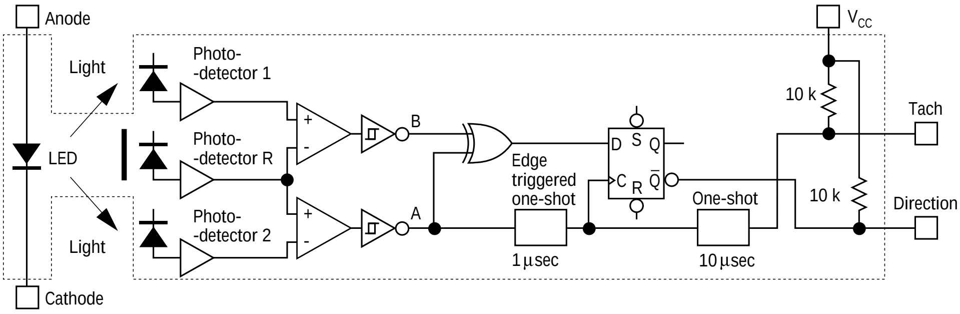
HOA0902 provides DIRECTION and TACH outputs directly. This is most useful in speed and direction control applications.

HOA0901 provides both A and B outputs. All four phases of position seen in the Output Timing Diagram in Figure 1 can be detected.

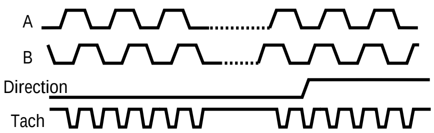
A and B channels can be decoded to sense direction and speed (as HOA0902 does), or position of the slot interrupter. Appropriate decoding circuitry can sense each of the four phases. Use HOA0901 for position, direction and speed control variables.

Figure 2

a. HOA0902 functional block diagram



b. HOA0902 output switching diagram



QUADRATURE DECODING OF HOA0901 OUTPUTS

There are several methods of decoding, which provide:

- Relative position
- Slot interrupter direction
- Speed of slot interrupter movement

The logic of A and B output quadrature decoding is shown in Figure 3. A level transition in either output triggers decoding. If the A output has changed polarity (1 to 0 or 0 to 1), then polarity of B is checked. If polarity is the same, the direction of motion is from B to A. If polarity is different, direction of motion is from A to B. Channel B acts the same way, except that direction is reversed.

Incremental motion is indicated by counting the edge transitions. Counting the transitions of both A and B provides maximum position resolution. Four counts are made for each slot as it passes the detectors. The quadrature states of the slot position are used for maximum resolution. If only the A or B transitions are used, two countable events per slot provide half the resolution. When only one transition polarity for A or B is counted, resolution is one count per slot.

The type of count decoding you use depends upon the resolution required and decoder complexity. The full quadrature counting decoder requires a fairly accurate slot interrupter. Slot width and spaces determine the distance between A and B channel polarity transitions.

The duty cycle of A and B outputs must be as close as possible to 50% in order to make the four phases equal in size. The source LED should operate at between 10 and 15 mA. For best results however, a duty cycle control loop is recommended. The A or B channels average to peak output level can be sensed to drive the LED current to a level which provides a 50% duty cycle. If the detector output is high for a larger percentage of the cycle than it is low, LED drive current should be increased.

Figure 3 illustrates the logical representation for a microcomputer decoder. The microcomputer uses a scanning procedure on its inputs from the A and B channels to activate direction and count update of position. Most microcomputers have input port event interrupts to facilitate the scanning.

If transition speed is too fast, or a microcomputer is not used, the circuit described in Figure 4 would be better. The logic you use should be 10 times faster than the expected arrival speed of the quadrature transitions. "4000" Series CMOS illustrates the concept.

The circuit in Figure 4 uses a clock input signal to sample the A and B channels to keep the logic synchronous. An edge noise filter may be added to remove extraneous noise on channel outputs. This may be needed if the electrical environment is quite noisy or the slot interrupter has vibration. The noise filter uses the clock period to detect at least two high or low samples in a row before indicating a polarity transition of the input. Thus, extraneous pulses shorter than a clock period are rejected. Additional stages can be added to the noise filter for more noise immunity.

Figure 3 Quadrature decoding algorithm

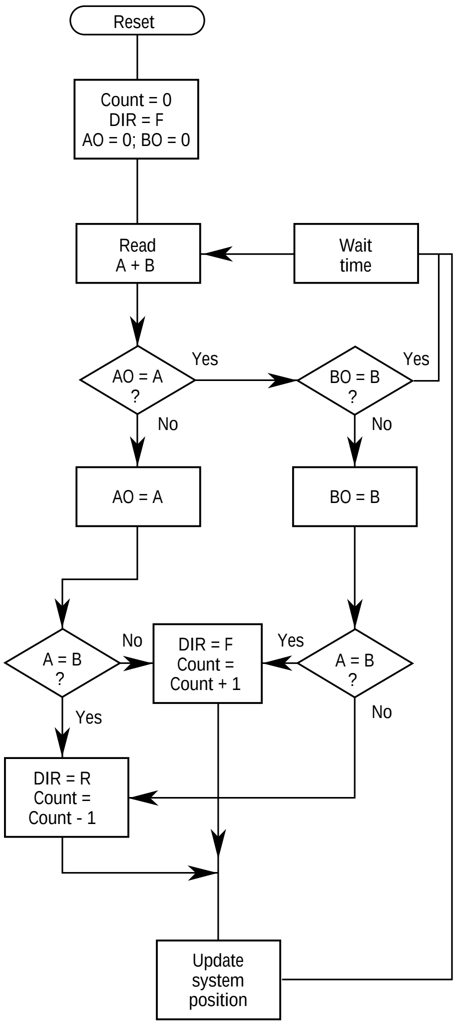
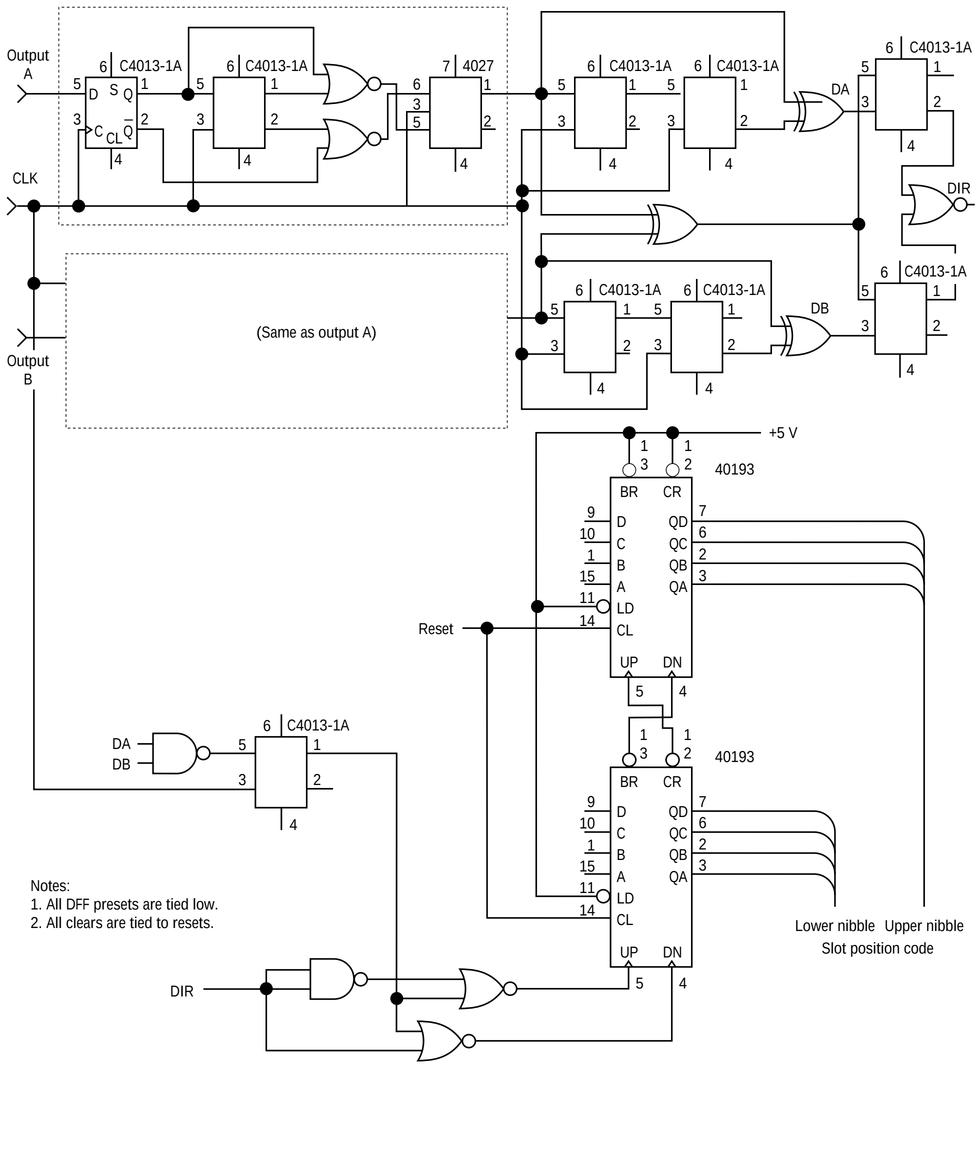
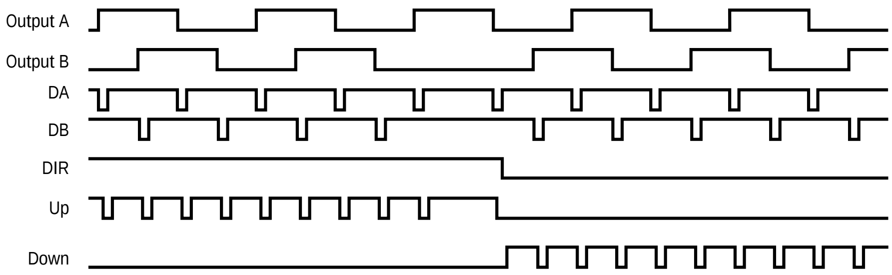


Figure 4 Digital quadrature decoder circuit



Notes:
1. All DFF presets are tied low.
2. All clears are tied to resets.

Figure 5 Quadrature decoding timing diagram



The clock should have a period which allows at least four samples per cycle (Figure 5) of the A and B outputs at their fastest speed of transition.

The circuit in Figure 4 counts both positive and negative transitions of both A and B channels in the 4 bit counters for maximum resolution. A maximum count of 256 is shown, but additional stages of counter can be added for higher counts.

If only one channel (A or B) is used, the noise filter and associated edge detector for the other channel can be dropped from the circuit in Figure 4.

DESIGNING THE SLOT INTERRUPTER

Good design of the slot interrupter is very important to create the quadrature outputs from the HOA0901 A and B channels. If you don't need the extra resolution of quadrature outputs, (for instance, counting the slot passages only, not the polarity changes at each quadrature state change), then you don't need a very precise interrupter. However, if you need full resolution, careful design is important to achieve the 90° phase relationship between the A and B outputs (as closely as possible).

The LED duty cycle control is the first step in creating accurate quadrature outputs. This insures the 50% A and B output duty cycle.

HOA0901 and HOA0902 both have .008 in.(.203 mm) wide detectors spaced by .001 in.(.0254 mm. To avoid spurious reflections, place a thin slot interrupter close to the detectors.

A 0.010 in.(.254 mm) thick slot interrupter placed 0.010 in.(.254 mm) to 0.020 in.(.508 mm) from the detector surface works well. A .011 in.(.279 mm) slot and .013 in.(.330 mm) bar is recommended for maximum resolution.

Note that the slot to bar ratio is not equal. To produce 50% duty cycle outputs when detector hysteresis is taken into account, the slots ***must*** be smaller than the bars. For HOA0901, the difference should be approximately .002 in.(.058 mm).

HOW FAST CAN THE HOA0901 COUNT?

HOA0901 propagation time sets the upper limit for the number of counts per second. We recommend a propagation time of no more than 6% of the fastest slot period. If V is the maximum slot interrupter velocity, then:

$V < .024 \text{ in.}/(16 \times 5\ \mu s) = 300 \text{ in./s}$

The maximum slot count rate is another limit on measurable rate:

Slot count rate < (1/16 slot x 5 μs) = 12,500 slots/s

If the slots are on a wheel of radius R, then the maximum revolutions per minute (RPM) possible are:

$RPM < [V/(2 \times 3.1415 \times R)] \times 60$

If R = 1 in., then:

RPM < 3000.