

Understanding Quadrature

Incremental optical encoders generate two data signals that are electrically 90° out of phase with each other. The term *quadrature* refers to this 90° phase relationship. Since each full cycle contains four transitions, or edges, an encoder that generates 2500 cycles/rev, for example, provides 10,000 edges per revolution.

In the twentieth century, the prevalent electronic circuitry of the day was based on "edge detection". The transitions coming from the encoder would act as the "trigger" to cause a count. At each transition, the electronics not only generates a count, but also determines direction of travel so that it knows whether to count up or down. This is done by establishing whether the transition is going high or going low, and what the state of the other signal is, as shown by the following table:

Forward Travel		Reverse Travel	
Chan A	Chan B	Chan A	Chan B
Up	High (1)	Up	Low (0)
Down	Low (0)	Down	High (1)
Low (0)	Up	High (1)	Up
High (1)	Down	Low (0)	Down

However, modern electronics look not at transitions, but at changes of state. (Yes, a transition is where a state changes, but that's English, not electronics.) Basically, the user's electronics contain a high-speed clock and constantly samples the states of A and B. When it sees a change, it counts up or down based on the following table, where 0,1 represents the states of A and B, respectively. Instead of waiting for a triggering event from the encoder, the electronics generates its own triggering based on its detection of a state change from the encoder. A subtle difference, but critical to the operation of modern digital circuitry.

Forward Travel		Reverse Travel	
From	To	From	To
0, 1	1, 1	0, 1	0, 0
1, 1	1, 0	1, 1	0, 1
1, 0	0, 0	1, 0	1, 1
0, 0	0, 1	0, 0	1, 0

Along with these eight "legal" state changes, there are also four possibilities that mean trouble: 0,0 to 1,1; 1,1 to 0,0; 0,1 to 1,0; and 1,0 to 0,1. When one of these occurs, it means that (at least) one state has been skipped. The user's circuitry is generally smart enough to generate an error signal warning that there's a malfunction somewhere. Since there are four distinguishable states (or edges) per cycle, it is extremely common for customers to take full advantage of the encoder's intrinsic resolution. In fact, there are off-the-shelf chips available these days to do this quadrature decoding; the user no longer needs to hand-wire his own circuit.

Why is UNDERSTANDING QUADRATURE important?

INDEX implications

With the old edge detection method, it was important that the index signal be tied to one particular transition; otherwise, the repeatability of the index would be lost. With a full cycle or half cycle index, the user would gate the high state of the index with the high state of channel A and a transition on channel B. The output of this gate would thus always correspond to the same edge of channel B.

With the new electronics, it is more important to tie the index to a particular quadrature state. The user can thus gate the high state of a full- or half-cycle index with the high states of channels A and B; the result will be a quarter-cycle index that is high when A

"there are off-the-shelf chips available these days to do quadrature decoding; the user no longer needs to hand-wire his own circuit."

and B are high. Or, Gurley can supply a quarter-cycle index directly out of the encoder; check the data sheets for availability.

TERMINOLOGY implications

Back when people were counting edges, it was often convenient to have the encoder vendor provide an output that not only identified a specific number of edges per cycle (1, 2 or 4), but also gave direction information directly. That's when Gurley started to offer pulse output. Pulses differ from square waves in 2 important ways:

- Pulse widths are of fixed time duration, whereas the width of a square wave ON state is a function of speed. (The distance between pulses is, of course, a function of position.)
- "Quadrature" has no meaning with pulse output; you get FWD pulses on one line, and REV pulses on another. (Or pulses on one line and direction information on the other.)

Pulse output options were fairly popular at one time, but it's been dwindling for quite a while. With the new quad decode chips available, the requirement has gone away, as long as the customer is using technology from the 1980's or later. On any of our newer encoders, pulses will no longer be offered.

What has survived is the terminology. Many encoder vendors, and therefore encoder customers, use the term "pulses per revolution" (PPR) when they really mean cycles per revolution of quadrature square waves. Because we still offer pulses, and because we're pretty deeply ingrained with the distinction, Gurley will not use "pulses" to mean anything but "pulses". (If the customer uses the word "quadrature", we know he means "cycles/rev".)

We used to say "4X multiplication" or "4X edge detection"; better terms are "quadrature decode" or "quadrature evaluation". We generally use "counts/rev" for what you get after decoding; "output steps" or "measuring steps" are also acceptable.

Because it can mean either cycles/rev or counts/rev, do not use CPR for anything other than a life-saving technique.

For more information, please call (800) 759-1844, or [click here](#).