Rotational Speed Measurement using QEP - Resolution Analysis

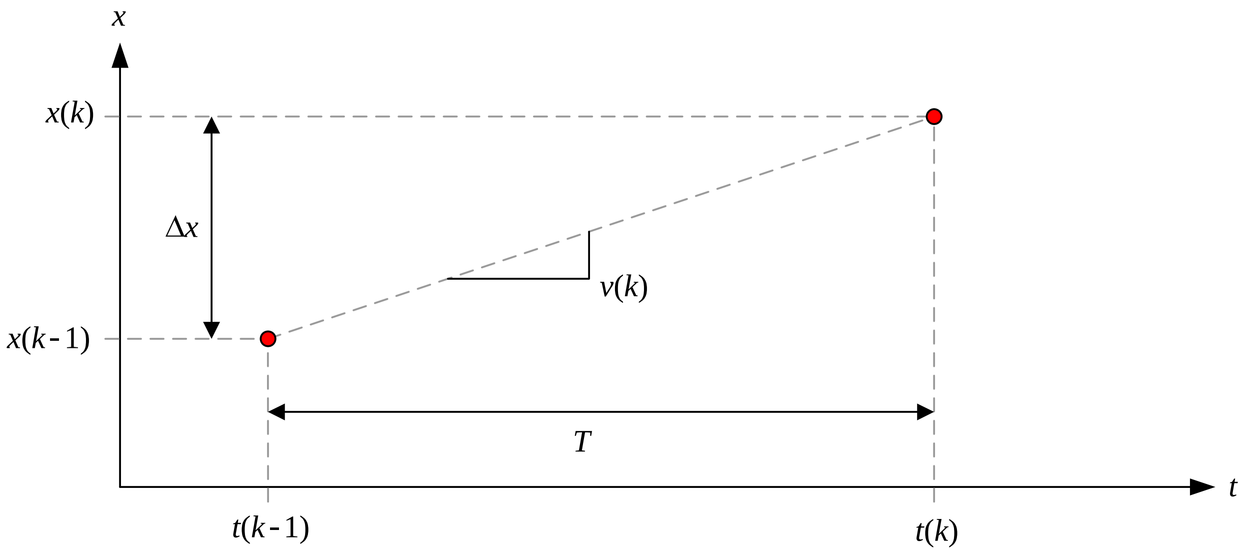
The following analysis covers rotational shaft speed measurement using a quadrature encoder. The input variables are encoder resolution in pulses/rev. (N), interrupt frequency in Hertz (f_{ISR}), and QEP clock frequency in Hertz (f_{QEP}). [qv. eQEP Module User's Guide, SPRUH18, p.445-6]

Mode 1: High Rotational Speed

Mode 1 applies when the rotational shaft speed is high relative to the control loop interrupt rate. In this mode a fixed rate control ISR reads an incremental encoder counter once each interrupt and calculates instantaneous shaft speed using:

$$v(k) = \frac{\Delta x}{T} \qquad \text{.......(1)}$$

Here Δx is the backward difference in encoder count between two successive interrupts at times $t(k\text{-}1)$ and $t(k)$, and T is the interrupt period.



The measurement resolution (normalised to 1) over the interval T is the ratio of encoder edge separation to interrupt period, both measured in seconds:

$$\varepsilon_1 = \frac{T_{edge}}{T} = \frac{1}{Tr} \qquad \text{.......(2)}$$

…where r is the encoder pulse edge rate in edges/second.

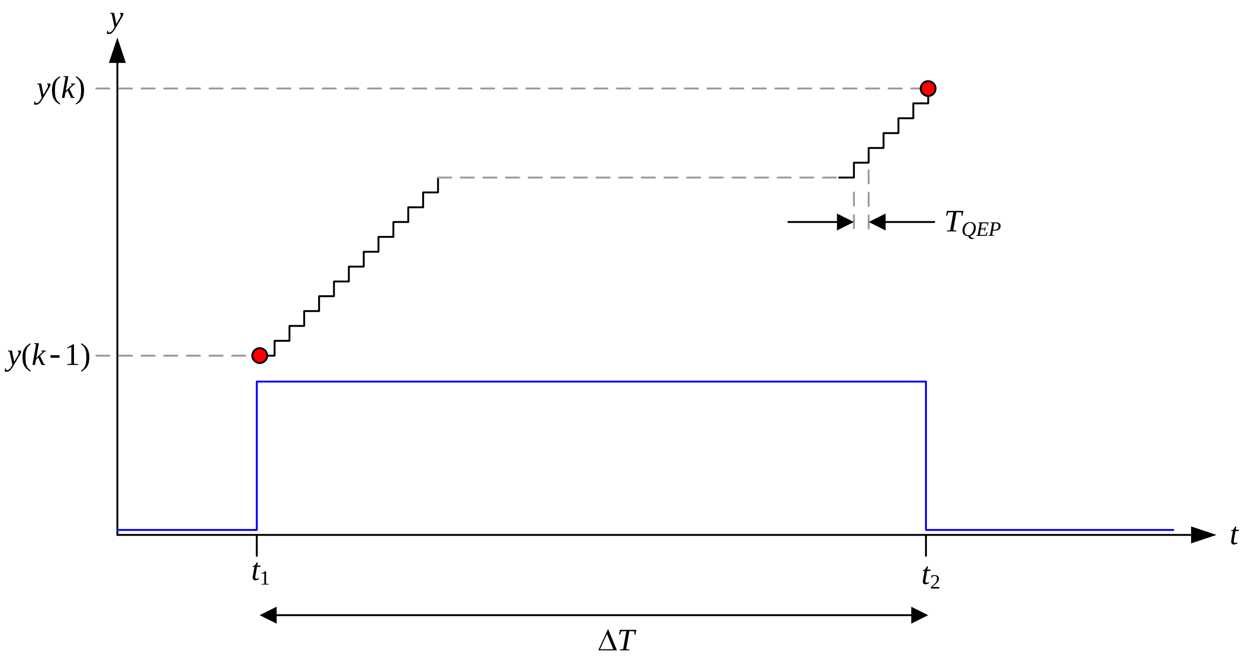
Mode 2: Low Rotational Speed

Mode 2 applies where the rotational shaft speed is low relative to the QEP clock frequency. In this mode the number of QEP clock periods between two successive encoder edges is counted, and shaft speed calculated using:

$$v(k) = \frac{X}{\Delta T} \qquad \text{.......(3)}$$

X is the rotational distance (i.e. shaft angle) between two adjacent encoder edges and ΔT is the time between successive edges measured by counting the number of QEP clock periods.

$$\Delta T = y(k) - y(k-1) \qquad \text{.......(4)}$$



The resolution of mode 2 is simply the ratio of QEP clock period to time separation of the measured encoder edges.

$$\varepsilon_2 = \frac{T_{QEP}}{y(k) - y(k-1)} = \frac{T_{QEP}}{\Delta T} \qquad \text{.......(5)}$$

The edge separation T_{edge} and time ΔT are related to the encoder edge rate by:

$$T_{edge} = \Delta T = \frac{1}{r} \qquad \text{.......(6)}$$

Optimum Resolution

Mode 1 will provide better measurement resolution at high speed whereas Mode 2 provides better resolution at low speed. Notice that equations (2) and (5) are related through the encoder edge rate, equation (6). The optimum rotational speed at which to change measurement mode occurs when the resolutions ε_1 and ε_2 are equal.

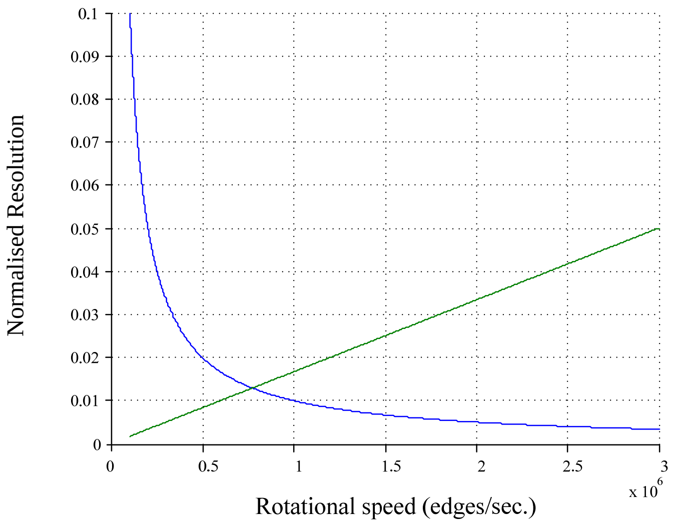
$$\varepsilon_1 = \varepsilon_2 \Rightarrow \frac{1}{Tr} = \frac{T_{QEP}}{\Delta T}$$

$$r = \sqrt{f_{QEP} f_{ISR}} \qquad \text{.......(7)}$$

We can now relate edge rate to physical shaft speed to find the rotational shaft speed *v* in revolutions per minute at which the measurement resolutions in modes 1 and 2 are equal.

$$v = \frac{\sqrt{f_{QEP} f_{ISR}}}{4N} \times 60 \qquad \text{.......(8)}$$

The plot below shows a typical case with: N = 2,048, f_{ISR} = 10 kHz, f_{QEP} = 60 MHz.



The cross-over speed is 378.22 edges/sec, which (assuming x4 edge mode in the QEP) corresponds to a shaft speed of about 5,673 rpm. If using best case mode, resolution would always be below 1.3%.