How can one get 4 times the accuracy of an encoder using quadrature encoders?

Generally, encoder's output signal is one square wave atleast, but quite often it sends two square waves with the phase shift at 90 degrees which is known as quadrature.

In optical encoders, LED light shines through a lens which focuses the light into column. That column hits a chip on other side of the disk with a photo detector area on it. Some parts of the detector area are assigned to channel A and others are assigned to channel B.

The sensors are alligned in such a way that Channel B is offset a quarter of an electrical cycle from channel A.

If A goes high before B → clockwise
B goes high before A → Counter clockwise.

The other advantage of quadrature is we can use the offset waveforms to effectively read each edge of line on encoder disk.

The encoder disk may only have hundred lines on it, but we can process the signal to get 200 or 400 pulses.

Channel A

Channel B

+5V

0V

+5V

0V

1X

2x

2x

4x
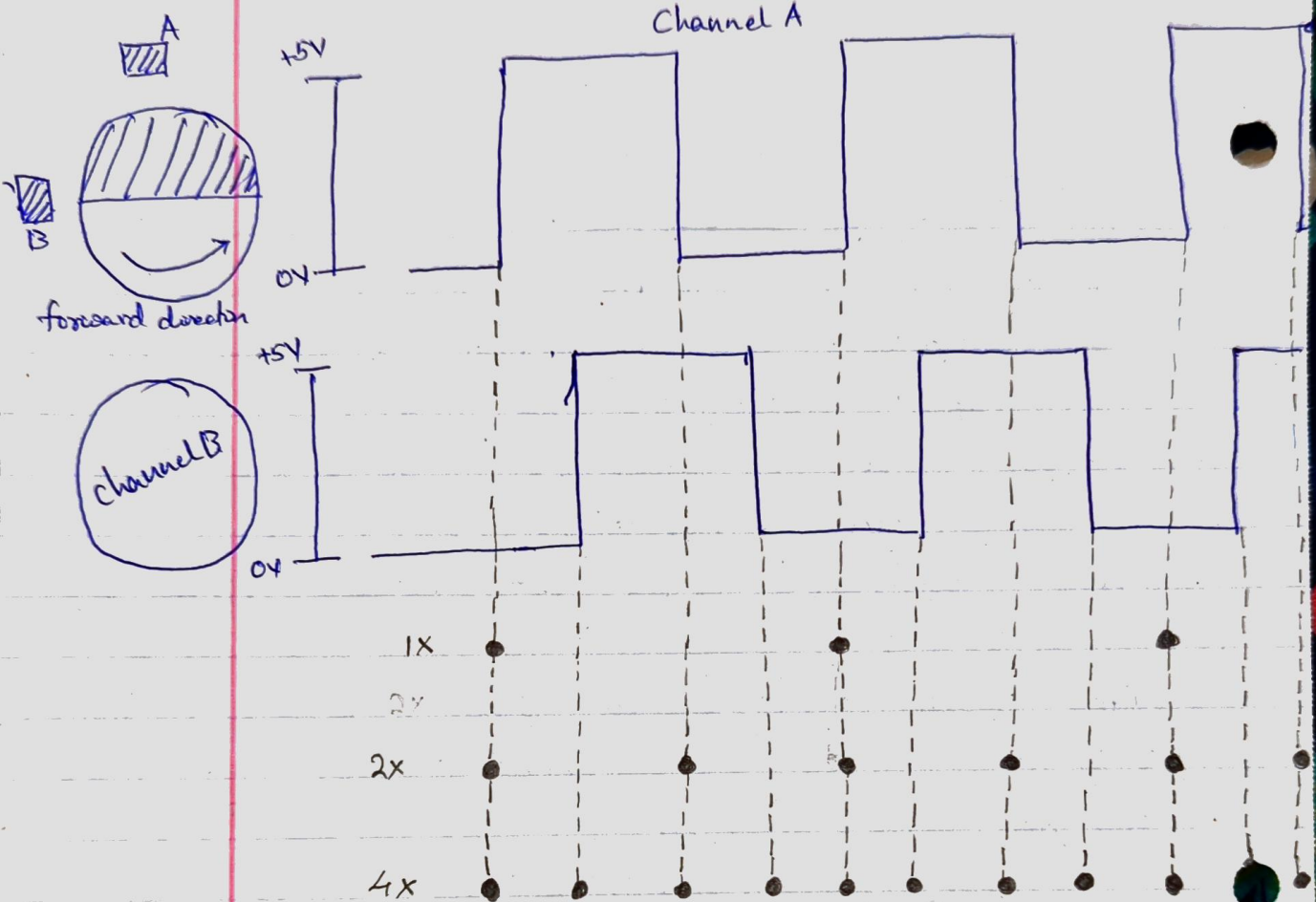
→ If you count each rising edge in channel A you get one pulse per cycle. Pulse count is equal to native resolution of disk

→ If you count rising and falling edges in channel A, we get two pulses per cycle. Pulse count is equal to 2 native resolutions of disk.

→ If we count both A & B rising and falling edges, we get four pulses per cycle. Pulse count is quadruple of native resolution.

☆ So, thus by having 4 pulses per cycle it has four times the accuracy.

Here one pulse per cycle, encoder was made to a four pulses per cycle encoder, there by 4 times (4x) improvement in resolution, which can lead to higher (4x) accuracy.