PICOMOTOR – OPEN VS. CLOSED LOOP

Open loop refers to a control technique that does not measure and act upon the output of the system. Most piezoelectric systems and inexpensive micrometer-replacement actuators are open-loop devices. While closed loop refers to a control technique that measures the output of the system compared to the desired input and takes corrective action to achieve the desired result. Electronic feedback mechanisms in closed-loop systems enhance the ability to correctly place and move loads.

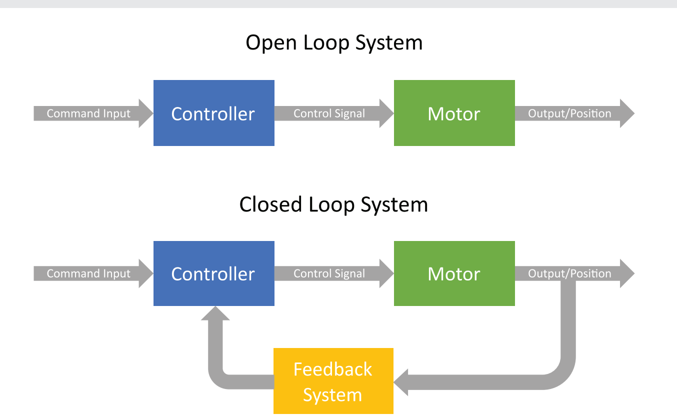

Figure 1

Open Loop System

Open loop is by no means a synonym for crude. Even inexpensive open-loop devices can achieve very fine incremental motions. Nanometer-scale incremental motions are achievable by open-loop piezo-type devices, like a Picomotor Open-loop systems infer the approximate position of a motion device without using an encoder. In the case of a piezo device, the applied voltage is an indicator of position. However, the relationship is imprecise due to hysteresis and non-linearities inherent in commonplace piezo materials. As a result, a standard Picomotor step size is not always the same between two Picomotors. Furthermore, as a result of the slip/stick mechanism the steps size also varies by load, figure 2. Still, for the same Picomotor with none varying load the step size stays the same.

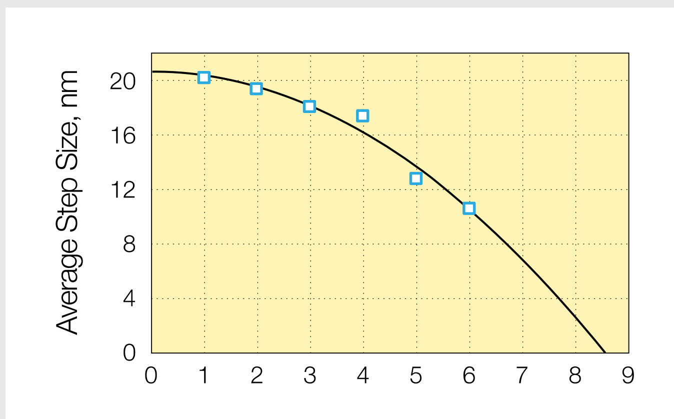

Figure 2

Another mechanism that affects Picomotor's step size is direction, which is an effect of the difference between expansion and contraction of piezo stack, figure 3. There is a big variation in the difference between forward and backwards step size, from 0% to over 100%, but always less than 30 nm.

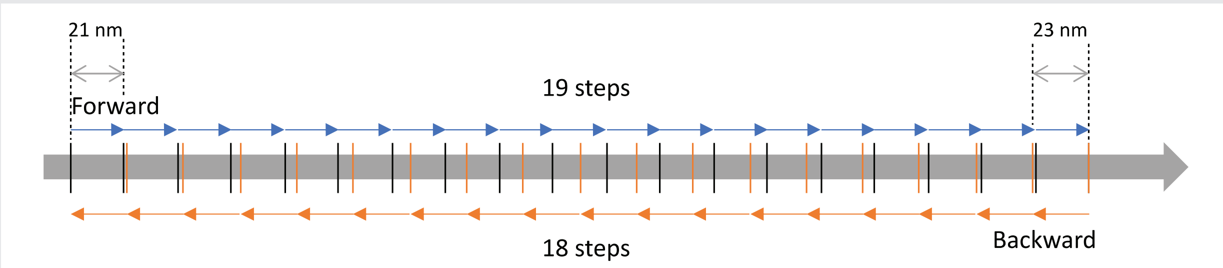

Figure 3 (please note dimensions are not to scale)

Even with this variability in the step size we are still able to adjust position at very small increments allowing for fine adjustments with very high stability. As you can see in example in figure 3, even though the Picomotor went forward and then backward 18 steps it will still be within 30 nm of the original position. Of course, for longer travel this becomes worse. Therefore, it is important to consider usage of open loop Picomotor for mainly small adjustments.

It is also always better to close the loop on the main process you are trying to control. For example with mirror mounts in an optical beam path it is better to close the loop through the beam position by utilizing beam splitters and beam position sensing detectors, like CONEX-PSD9 or CONEX-PSD10GE, which will allow you to figure out how to command the Picomotors on the mirror to adjust the beam position. In application like this closed loop Picomotor wouldn't have helped with the actual adjustment.

A good example of this is beam alignment inside the cavity of a laser. There it is impossible to adjust mirrors manually after the cavity is closed, but at that time point the adjustments shouldn't be more than a few steps in one or other direction making open loop Picomotor a perfect fit.

Closed Loop System

It can be advantageous to close the position loop on a Picomotor. The main reason to do this is when you need to fully automate positioning, meaning the system is far from its optimal position. To better understand it is best to look at an example, but first let's look at the encoder resolution and step size.

On the closed loop Picomotor the encoder resolution is slightly larger than step size and the reason for this is that we want to be able to command the Picomotor to go to a specific encoder count and figure 4 explains how that is achieved.

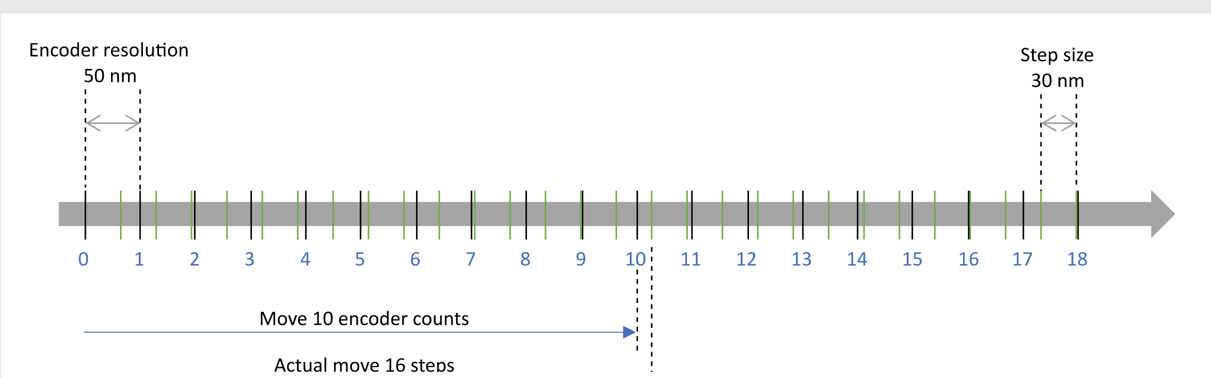

Figure 4

In figure 4 we are commanding the Picomotor to move 10 encoder counts. To achieve this the controller commands the Picomotor to move 16 steps. During the 16th step the encoder hits the 10th count, but since the Picomotor has a fixed step size it will finish the step and overstep the position of the 10th count. The worst-case scenario of this overstep results in error always less than the step size.

If you have the encoder resolution smaller than the step size, you get into complications that aren't helpful in using the actuator in an application. In figure 6 you can see that the step size decides the position and it's impossible to achieve a specific encoder count in between steps

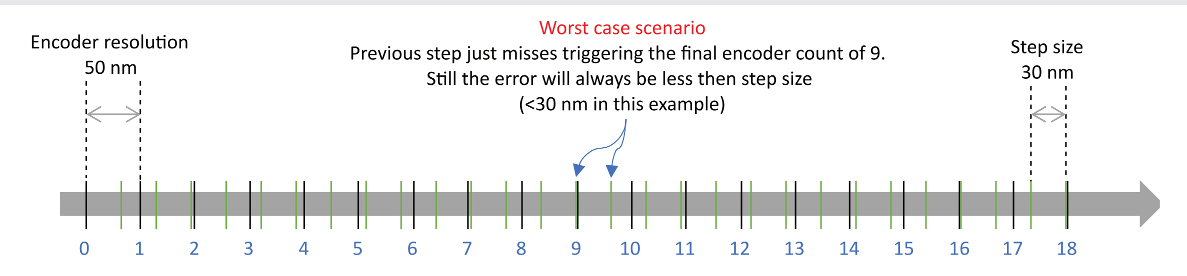

Figure 5

The impossible encoder position makes it very complicated for the controller and user to go to a position based on encoder counts.

Now, let's look at the example we talked about at the beginning of this section. Let's consider an application where we have a linear stage that is carrying a mirror mount. The linear stage needs to move between two positions, so the laser beam hits one of two targets. Figure 7 shows the linear stage and Picomotor in the two different positions, depending on which target the laser beam hits.

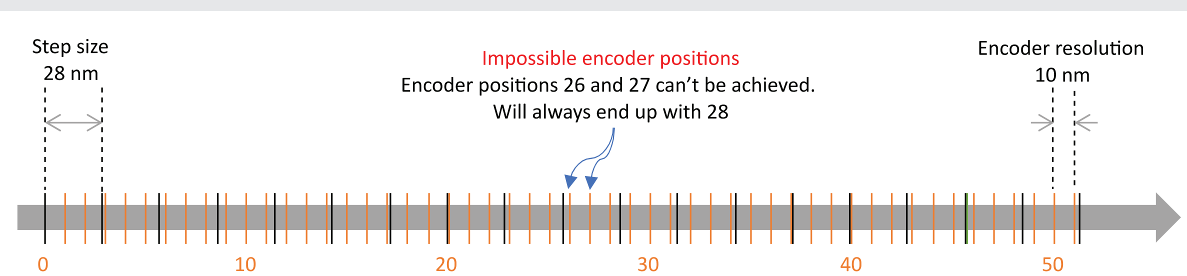

Figure 6

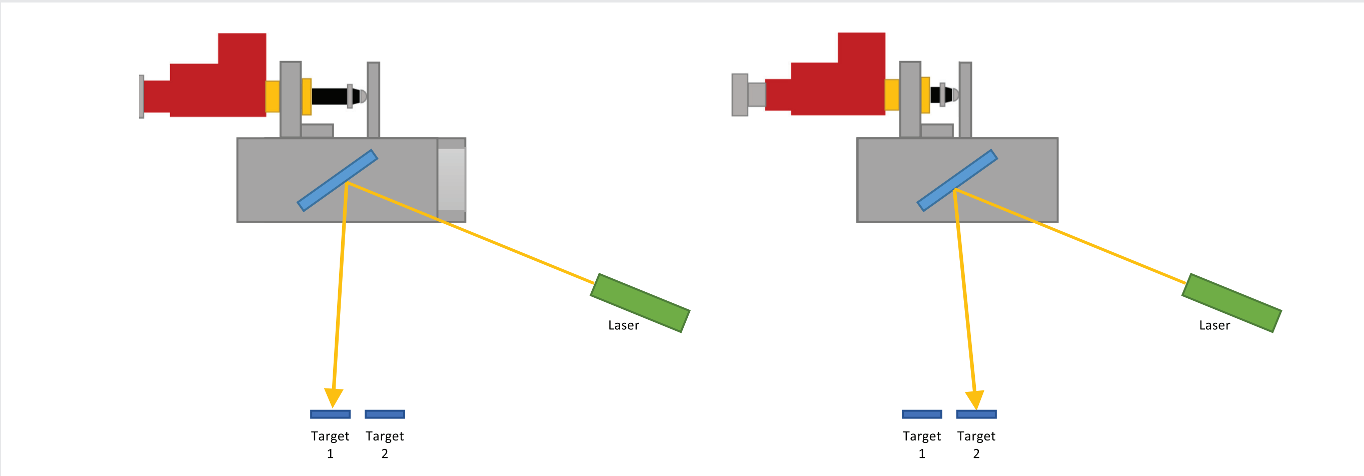

Figure 7

For this example, let's say that the move is 10 mm. This would mean 200,000 encoder counts (based on 8311's encoder resolution of 50 nm), but as we talked before the steps in one or the other direction can be very different, the average step forward is about 21.4 nm and backwards 25.5 nm. That would mean forward it would take 467,390 steps and backwards nearly 392,157 steps. Big difference in the number of steps and therefore open loop wouldn't be practical, unless you had beam position sensing detectors, like mentioned earlier, but still that would be a much slower process as you would have to go back and forth between moving the Picomotor one step and then checking position on the sensor, and then doing it again and again, until you reach the desired position.

With closed loop Picomotor you would just tell the controller the number of encoder counts to move the actuator and it could optimize the acceleration, speed and deceleration to minimize time it take to get there.

Conclusion

As can be seen above the application will determine the appropriate Picomotor, open or closed loop, to use. Where there is a need for very small, infrequent adjustments combined with a higher system level feedback, like beam path position sensing, open loop makes more sense and the added cost of closed loop isn't necessary. Closed loop makes more sense if there are well known positions that the system must adjust to, two or more. In those kinds of applications closed loop can be very valuable in cutting down the time it takes to move from one position to another.
If you have any further questions, please contact your local sales contact and we will gladly help you in assessing what makes more sense in your application.

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