A Method for Controlling Laser Spot Locations in a Polygon Scanner

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Polygon scanners offer a way to rapidly and accurately place ultra-short laser pulses on a surface. Determining precise spot placement is a challenge with polygon scanners. The location varies with polygon speed and laser clocking. A controller which reads the position of the polygon may be used to output a clock signal to the laser causing the laser to output a pulse at defined periods. To achieve shorter periods, which translates to closer spacing, it is desirable to add consistent time offsets or delays to the clock signal. A laser that has a high internal clock may be configured to delay a specified number of high frequency clock periods before emitting the pulses. This provides more precise spot placement.

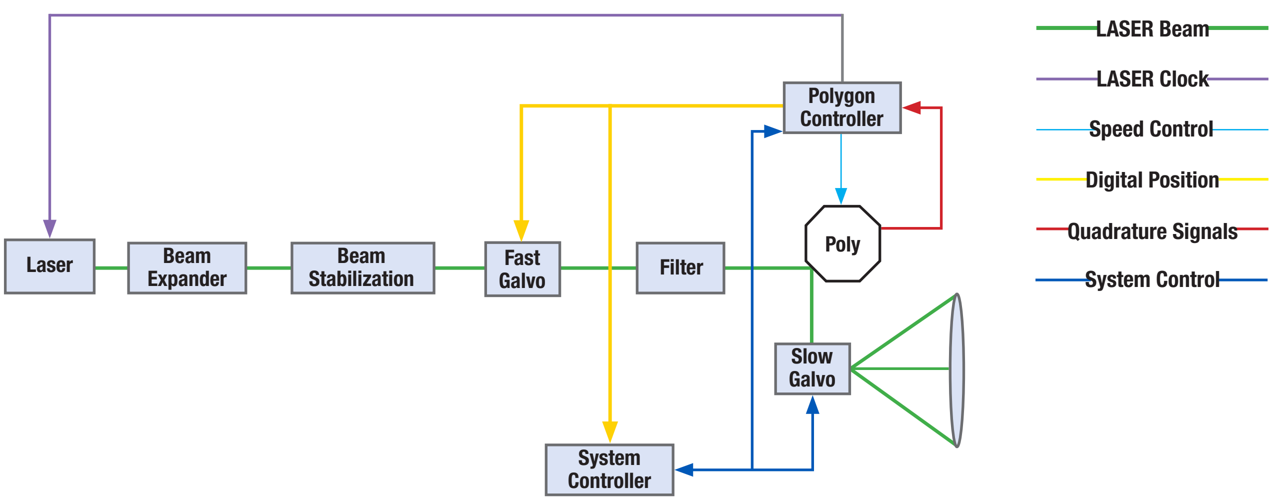

Figure 1. Detector calibration system block diagram. [1]

A representative polygon scanner system architecture is illustrated in Figure 1. In this system, a laser beam enters a beam expander. The expanded beam position is corrected through a coarse beam stabilization setup to compensate for thermal drift and large path errors. Imperfections on the polygon surface (facet) may be corrected with the fast galvanometers. These galvanometers, combined with filtering, are intended to repeatedly place the laser spot in the same location on each facet throughout the laser pulse window. With stable polygon spindle rotational speed, this results in consistent spot arrays with precise fixed spacing. The laser spot sequence is then reflected off the rotating polygon and into a low speed galvanometer for row placement.

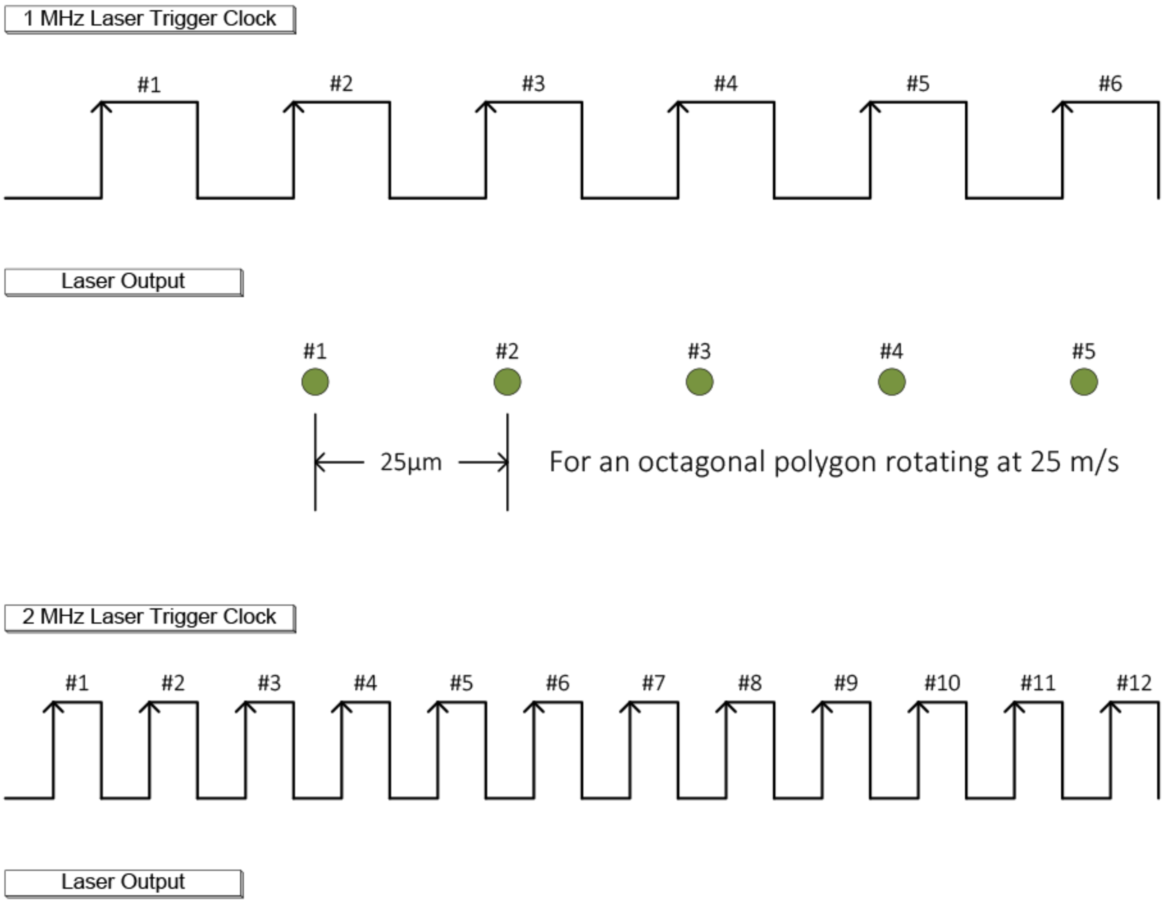

Figure 2. Basic Polygon Laser Operation

Figure 2 shows an example laser output with 1MHz and 2MHz input trigger clocks. Spot to spot spacing is provided for an octagonal polygon rotating at 25 meters per second.

To achieve finer spacing tolerances, the laser trigger clock could be varied or the rotational speed of the spindle varied. However, this may not be desirable. Ultra-fast lasers are designed to operate at fixed frequencies and may not tolerate wide clock spans. Variable spindle speeds may also result in inconsistent spot placement depending on delays between the position and laser trigger.

Because the output pulse is synchronous with the laser's internal high speed clock, it is possible to delay the output pulse by a pre-determined number of internal clock cycles. By varying this number of cycles, the spot spacing could be subdivided into tighter spot spacing if the work surface is not moved.

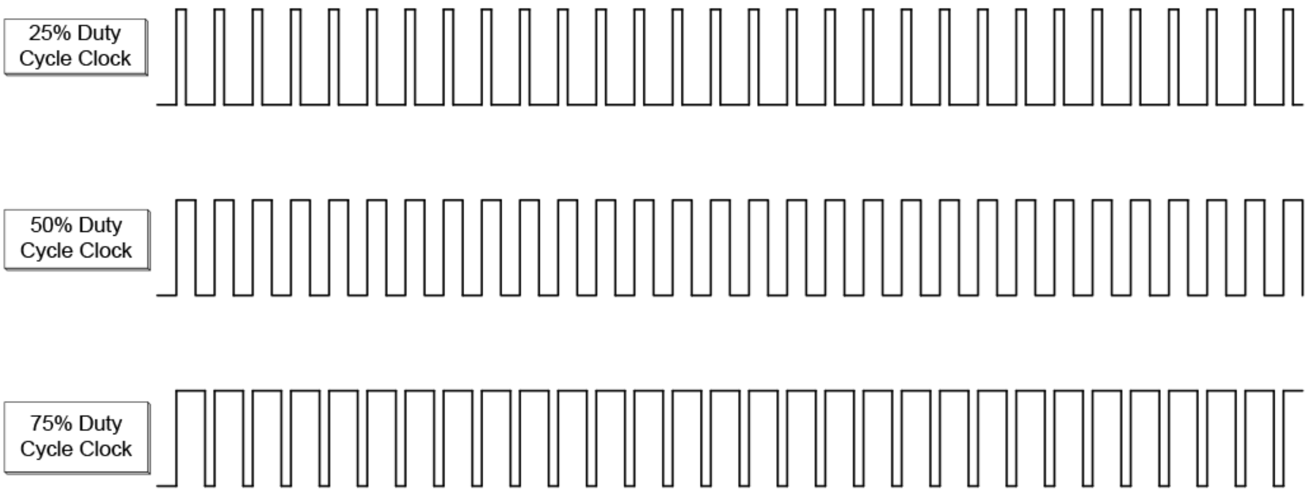

Figure 3. Duty Cycle Illustration

The duty cycle of a clock is the time the clock is high (ON) versus the time it is low (OFF). In Figure 3, three duty cycles are shown. In the first pattern, the clock is high (ON) for 25% of the full cycle. This represents a 25% duty cycle clock. In the second pattern, the clock is high (ON) for 50% of the cycle. And in the third pattern, the clock is high (ON) for 75% of the cycle. Changing the duty cycle may also be viewed as changing the pulse width. This is also referred to as Pulse Width Modulation (PWM) and is a method of providing a control signal through a clock.

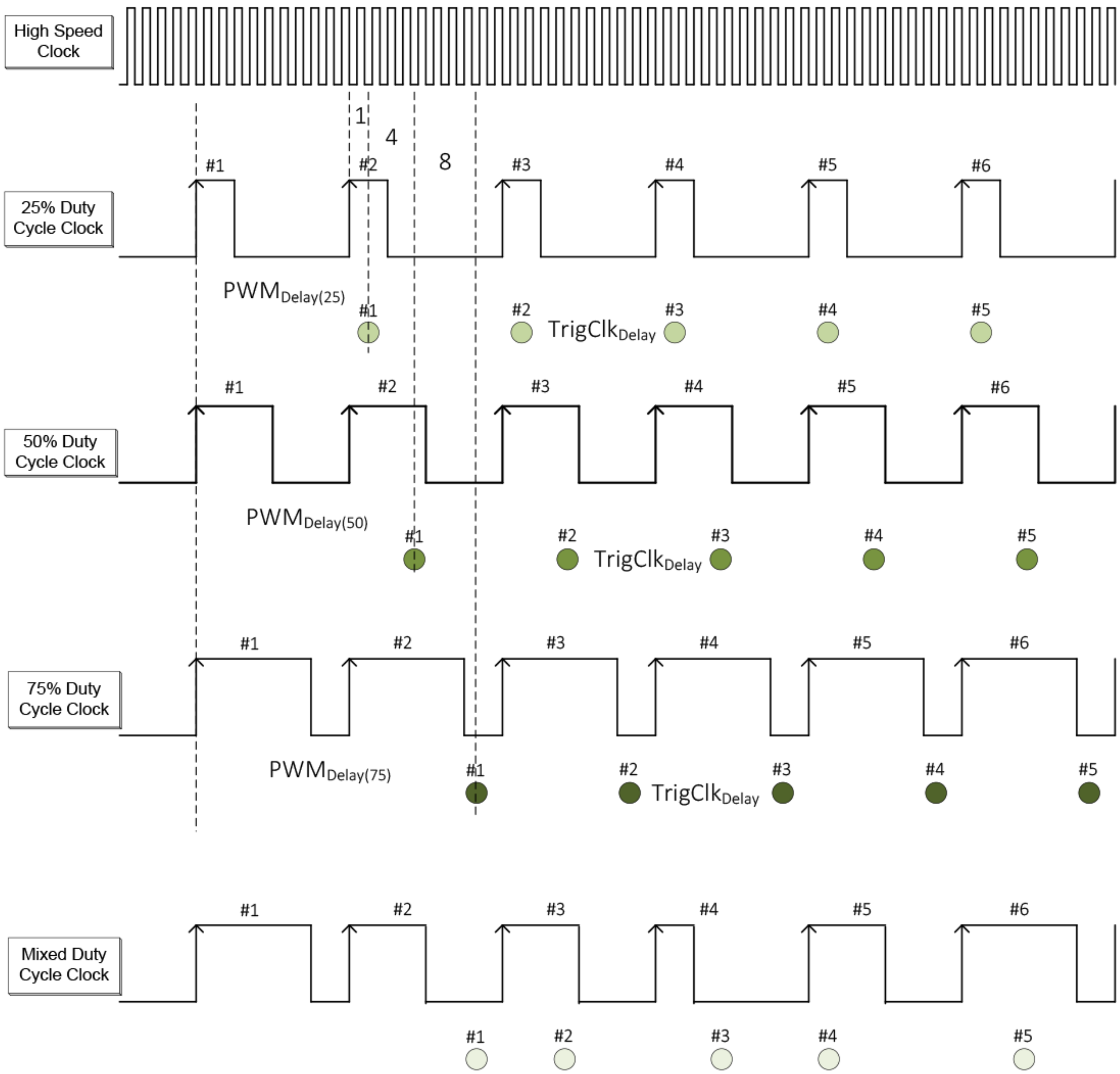

Figure 4. PWM Laser Operation

It is proposed to use the clock pulse width to determine the number of internal clock cycles to delay before outputting a pulse. Figure 4 illustrates this operation. The high speed clock is the high frequency internal laser clock. It is typically ten to one hundred times faster than the desired laser trigger clock. The rising edge of the input clock initiates a counter which counts the number of high speed clock transitions before the falling edge of the input clock is received. In the example, the 25% duty cycle clock has two high speed clock cycles during the on time. This results in a minimal one cycle delay before the laser pulse is output. During the 50% duty cycle clock, four high speed clock cycles are counted during the on time. This results in a four cycle delay before the laser pulse is output. During the 75% duty cycle clock, six high speed clock cycles are counted. This results in an eight cycle delay before the laser pulse is output. Combining the results, if the work surface is not moved, there will be two additional spots between the original spot spacing. The overall result is finer spot placement control.

The PWM delay may be represented as:

$PWM_{Delay} = 1/f_{trigger} + (n \bullet 1/f_{highspeed})$

where $f_{trigger}$ = frequency of trigger clock,

n = number of clock pulses from high speed clock,

$f_{highspeed}$ = frequency of high speed clock

It is recommended that the minimum pulse width is two or three high speed clock cycles and the maximum pulse width is two or three clock cycles less than the maximum number of high speed clock cycles in the output trigger clock.