Optical Timing Accuracy

the weakest link to accuracy

Timed events generally required accuracy of hundredths (0.01) of a second or thousandths (0.001) of a second. Timing system manufacturers often state the accuracy of their timing products as ten-thousandths (0.0001) or even hundred-thousandths (0.00001) of a second. This is most likely true of the actual timing circuit but there is more to consider when rating the accuracy of the entire timing system.

The Timing Box

A timing system starts with a crystal controlled, microprocessor based timing box. Microprocessors can time events at high speeds and the consistency of their clock dictates their accuracy. Since everything changes with temperature, timers with hermetically sealed crystals or oscillators can provide stability over a wide range of temperatures. The ability to time an event to several decimal places is not difficult with today's technology. Keeping the timing consistent with environmental changes is one aspect of an accurate timer. High quality timers pay attention to the stability and accuracy of the timing circuit inside.

Polling Frequency

Accuracy can be greatly limited by how often the timing box checks for trips from the start and finish lines. If the timing box checks the start and finish lines every tenth of a second, accuracy will be limited to a tenth of a second regardless of the speed the CPU chip operates at. Generally, high quality timers poll the sensors at a much higher rate than the minimum accuracy levels. This may sound like a very basic concept, but there are timing systems based on a PC as the timing unit and polling the start and finish lines 100 times a second. The result is 1/100 second accuracy limited by the PC's ability to poll its I/O line fast enough. Add in the interrupt system of the PC servicing other PC functions and the polling of the I/O lines may be fast enough but becomes irregular. The result is the accuracy varies based on what else the PC is required to do while running the timing software, like servicing a hard drive or update the screen, etc.

Optical Sensor Types

Two types of sensors exist in timing systems today, a solid beam of light and a pulsed beam of light.

The solid beam of light uses a continuous light source illuminated all the time much like a light bulb in your living room. The sensor receives the beam of light and waits for the beam of light to disappear (blocked by an object), then sends a signal to the timing box. If the sun is too bright, the solid beam may be blocked but there is sufficient ambient light to fool the sensor and the trip is missed. Some laser light source systems depend on the laser light being much brighter than the sunlight to overcome the ambient light issue. A better solution but still subject to ambient light issues.

There is a delay characteristic for each detector when the beam is blocked. The response time for the detector is the delay measured from the time the beam is blocked until the point in time when the timer receives a signal from the sensor of a beam trip. Every sensor has a delayed response time and does not effect the timing as long as the start beam is delayed the same amount of time as the finish beam. Photocell based sensors tend to be slow response components, while solid state phototransistor based sensors tend to be very fast response components.

The pulsed beam of light is an intelligent solution to overcome the ambient light issue. The light source is flashing at a set rate and the receiver is not only receiving the light beam, but is also ‘tuned’ into the flash rate of the light source. The sun does not flash so the sensor can easily distinguish between the flashing light source and the ambient sunlight. An important factor here is how fast the light source flashes, known as the frequency modulation. The faster the flash rate, the higher the frequency, and that will be a major factor to determine the response time of the sensor. With a modulated light source, the beam is continuously turning on and off so the receiver no longer is looking for the absence of light. The sensor must interpret how long the beam must be off before it can distinguish between the flashing of the light source and the blocking of the light source during a beam trip. The response time is much more stable since the sensor is counting the number of pulses absent and then sending a signal to the timer. The more complex the modulation of the light beam, the more equally consistent two different sensors will be when tripped and the more reliable the sensor will be in varying sunlight levels. The more consistent the sensing, the more consistent the timing, and that makes for higher accuracy.

Response Time and Latency

There is a unique balance to the optical sensor. If the sensor responds too quickly, small rocks or dust or even rain will block the beam for a short period of time and send false trips. The response delay of the sensor must be long enough to eliminate the small unwanted items from tripping the sensor. The response delay also must be short enough to ensure fast moving objects will block the beam long enough to detect a beam trip. Once the beam is blocked, the missed light pulse counting begins, the consistency of the number of pulses missed determines the latency of the sensor’s response. The latency is how much the sensor response time varies from one trip to another. Since every missed light pulse adds to the response time, the sensor’s response latency is a combination of the range of missed pulses allowed and the flash rate of the light source.

How does this effect timing? Let’s consider a high-speed sensor in the perfect world that can respond in the 5 to 7 millisecond range. Let’s say the start beam trips, and 5 milliseconds elapse before the timer receives a trip signal from the sensor. Now the finish beam trips and 5 milliseconds elapse before the timer receives a finish signal. The net difference is zero and the accuracy is left up to the accuracy of the timer. On the other hand in the real world, the start delays for 5 milliseconds and the finish delays for 7 milliseconds, the measured time is high by 2 milliseconds. The latency is 2 milliseconds (response ranges from 5msec to 7msec) making the accuracy of the timing plus or minus 2msec, or, 4msec. This is due to the fact the next run could result in the start beam sensor delay at 7msec and the finish at 5msec resulting in 2 msec less on the time One time its 2msec high, the next time could be 2msec low.

Latency of the sensor must be in the microsecond range to ensure accuracy in the thousandths of a second range. Measuring the variation of the sensor’s response time while repeatedly tripping the beam will provide the latency level of the sensor. Latency is the one timing component setting the greatest limitation to the accuracy of the entire timing system.