How It Works

General Overview

The Pcount photon counter is designed to interface to any optical detector that can produce a positive or negative voltage pulse larger than 300 microvolts, and yields CONTINUOUS time-correlated single photon counting. There is no dead time, start-stop time, counter switching, FIFO (First In First Out) buffer size limit, or lost photons. To accomplish these things, a new design of electronics was implemented that is very different from other counters. The purpose of this white paper is to describe how the counter works in general so that one may understand if it is of use in your application. I suggest reading this paper and then looking at the demo video under the gated photon counter tab for a working example of data gathering.

The input to the Photon counter is usually through the PV16 variable gain comparator (threshold level sensor) that is connected closely to the detector so that data may be transmitted through 50 ohm Coax cable to the Pcount. The PV16 gives the best possible timing, is very easy to use, and is compatible with the Hamamatsu Hybrid photomultipliers that are the best detectors for GHz counting. For legacy compatibility, the Pcount can be configured to accept LVTTL pulses up to 1 **GHz**. That is not a misstatement, LVTTL can run in excess of 1 GHz now.

The most important feature is the use of **USB 3 SUPERSPEED** for continuous streaming of data to the computer in real time, without loss or delay or size limit or time limit. Obviously the data cannot exceed the size of the disk, but NVMe disks which are fast enough to record data at **400 Megabytes/second** are now available in 2 Terabyte and 4 Terabyte sizes. The previous Pcount photon counters used USB 2 which had a limit of 500 Kilo-Bytes/channel or about 4.09 million photon counts before the FIFO was filled and the USB 2 had to stop to transfer to the computer. Many photon counters have this FIFO limit even if they do not depend on USB.

Once the Pcount is turned on and the reset is toggled, the photon counter can be triggered in several ways and will continuously take and store photon data until it is stopped in hardware or by software.

A C++ stand-alone program starts and controls data collection to the computer hard drive through USB 3 speeds of 200 Megabytes/second or 400 Megabytes/second for a selected number of bytes. The size is only limited by the size of the hard drive. There is no need for program installation or a dll, and the program is compatible with any Windows version that has a command prompt for simplicity and compatibility. The data bytes containing photon counts are in binary format and may be read with many programs including IDL, Matlab, Labview or a custom program. The acquisition program may be started from a higher level language such as IDL under windows interfaces.

There are numerous options for data gathering. One might take data for a fixed time and then simply sum the number of photons. The counting is TCSP (Time Correlated Single Photon) Counting in bins of either 1 ns or 1.25 ns or 0.625 ns wide. The latter case needs 16 bits whereas the first two use 8 bit bytes allowing for more channels.

The input to the Pcount is an edge-triggered 4 GHz divide by two flip flop with typical 120 picosecond output rise time. With logic, the photon events are put into bins without the possibility that edges on the logic can miss a pulse through coincidence or setup and hold times. So the data are recorded in NRZ (Not Return to Zero) logic which has two benefits. First, it reduces the needed bandwidth, and second, it makes it easier to see photons in a plot of raw data. An example might be the following where each bit corresponds to a nanosecond bin:

00001111 11000000 for two random data bytes. When the first byte goes from 0 to 1, a photon has occurred. The level will continue at the 1 level until the second photon returns it to zero. If the data is 11111111 01010101 then a burst of 8 photons occurred in the second byte. Logically the photons can be extracted by shifting the data by one bit and running an Exclusive Or between the data streams. Exclusive or outputs the following

bits compared yield

1	1 >	0	No photon
0	0 >	0	No photon
1	0 >	1	one photon
0	1 >	1	one photon

A file of consecutive bytes is written to disk which can be quickly decoded and plotted raw making it easier to see the photons since one photon in 10,000 empty data points cannot be easily seen on most computer monitors.

Features

The photon counter can be gated. That means that one can take data and turn on the data taking when data of interest might be available. This is especially useful when there are bursts of data followed by long intervals of no data. This feature eliminates starting the counter multiple times followed by a reset which is slower than the nanosecond gating.

The photon counter may be externally triggered. The start up of data gathering begins with only about one nanosecond delay and continues until stopped. When the photon counter is triggered, a LVTTL level on the back of the counter goes from zero to one.

For convenience or for synchronization with other devices, there is an 800 MHz clock output and a 100 MHz clock synchronous with the data These also verify that the unit is properly operating which might not happen if the unit reset is skipped.

There is an AC coupled LVPECL gate out on the back that mirrors the input gate so that the gate can be optimized with the front panel level adjustment for different input gate rise times. One wants to avoid multiple gates on the rising edge of the gate pulse input.

For reference, the command line for data gathering is presented:

PhotonLogger.exe examples

Reset the logger interface:

PhotonLogger.exe -r

Take 1000 Megabytes of four byte Data:

photonlogger -F filename.bin -L 1000 -32

The photon logger takes only two byte data (first 2 channels) by default. So the -32 is necessary to take data from all four 100 MHz bytes.

One could take 100 files of data 10 megabytes long instead of taking a single file of 1000 megabytes for processing convenience.   IDL can handle gigabytes of data so that very large files may be analyzed for events but sometimes smaller is better.

The new USB 3 Superspeed also has triggering and gating from LVTTL input in the photonlogger program.. The hardware gating and triggering is very fast, but if the start and gating are not nanosecond critical, it is easier to use LVTTL input to trigger and also gate the data after triggering. However, both hardware triggering and USB 3 triggering can be used in many combinations.

The Pcount G may be easily customized for various options such as TTL input and PV16 input, larger or smaller bin sizes, and even for OEM boards. Multiple TTL inputs can be combined with pulse-narrowing one-shots and added together for higher count rates.

A new feature is the output on D-Sub connectors of various LVTTL outputs that can be acquired with a logic analyzer. This eliminates the need for a multiple GHz oscilloscope and gives a real-time state of the counter. For example, the latch value of the first bit of every byte allows one to verify that the counter is counting on that channel.

Another new feature is the inclusion of an ~100 MHz LVTTL output on the back of the unit for testing and setup. This feature eliminates the need for an external pulse device to verify data collection and revise software.