

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 LVTTTL pulses up to 1 GHz.

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 a 1 GHz clock output and a 125 MHz clock synchronous with the data bytes or an 800 MHz clock and 100 MHz synchronous clock. These also verify that the unit is properly operating which might not happen if the unit reset is skipped.

There is a LVTTL gate out on the back that mirrors the input gate so the gate can be optimized with the front panel level adjustment for different input gate rise times.

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

PhotonLogger.exe examples

Reset the logger:

```
PhotonLogger.exe -r
```

Log 10MB of data to filename.bin:

```
PhotonLogger.exe -f filename.bin -l 10          the -l is minus L not minus one
```

The number 10 might be replaced by 1 to 100000 etc for 1 megabyte to 100,000 megabytes. This program is normally called by a high level program such as IDL so that data taking is automatic.

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.

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.