

A LabVIEW Based Counting Photons Existence in the Light

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Abstract—Lab VIEW, developed by National Instruments, is a graphical programming environment suited for high level or system level design. It allows integrating different signal processing components or subsystems within a graphical framework. This paper introduces a LabVIEW based counting number of photons in the light. The probability of the photon existence is calculated in a separated SubVI using LabVIEW. In this paper the data acquisition card NI-PCI 6602 is used for this purpose.

Index Terms—Lab View, Photons existence, Data acquisition.

I. INTRODUCTION

In 1905, Albert Einstein published the theory of photoelectric effect, which gave the idea of photons to describe the origin of light. This theory extended from classical radiation to quantized radiation, leading to a clearly point of view of the statistics of light. The understanding of the interaction between light and matter following from these developments formed the basis of quantum optics.

After the introduction of the correlation experiment in 1956 and also the forming of quantum formulation of optical coherence by R. J. Glauber, this field started to flourish. Many experiments based on entangle photon pairs and quantum emitter such as using trap ions, quantum dots, molecules and colour centre have been studied intensively to realize their potential as a single photon source [1].

LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) is a graphical programming environment, developed by National Instrument (NI), which is well suited for high-level or system-level design. This programming approach is based on building blocks called Virtual Instruments (VIs) [2, 3].

In this paper, a LabVIEW program is used for counting the photons in the light through DAQ card model NI-PCI 6602E of National Instruments. The objective of this paper is setting up the detection apparatus and automates the data acquisition system for single photon detection. Automation for the detection requires a programme that can count for the coincidence and raw counts of the counter. Besides, it can also calculate second order correlation values for the collected data.

II. SINGLE PHOTON SOURCE

Single photon source is a source that can produce photon with antibunching characteristic. In general, antibunching

characteristic is a quantum state of light where the photon statistic deviates strongly from the classical distribution [3]. For example, if one photon state was sending to a beam splitter and photon counting detectors were placed at the transmitted and reflected beams position, no coincidence will be observed. From the principle of quantum mechanics, the wave function of the photon has to collapse onto either one of the two detectors. The probability of obtaining two or more photons at the same time is negligible. Figure (1) shows the difference between a triggered classical photon stream and the triggered single photon stream (ideal). An ideal single photon source emits one photon with certainty or in a specified time interval [4].

In this paper, the automation system for single photon generation and detection is based on color center in diamond. Color center is also called nitrogen vacancy. The reason for choosing this approaches are:

- Suitable for room temperature
- Much simpler setup than any other quantum emitter approach

As for the automation of the detection, it will enable computer to counts the coincidence and raw data counts from the single photon detector. Besides that, second order correlation values can be calculated as described later.

III. DATA ACQUISITION SYSTEM

Data acquisition system involves gathering signals from measurement sources and digitizing the signal for storage, analysis and presentation on computer. Three main components to be considered in the systems are [5]:

- 1) Signals: The signals are standard logic pulses coming from the detectors.
- 2) DAQ hardware: DAQ hardware acts as the interface between the computer and the outside world.
- 3) Driver and software.

Connector block (CB-68LP, National Instrument) as shown in Figure (2) is a necessary needed for connection to DAQ card in computer. It uses a 68 I/O shielded cable (SH6868, National Instrument) for data transferring process.

It is possible to use the versatile National Instruments counter/timer DAQ card NI-PCI 6602E device shown in Figure (3) to create a wide variety of measurement solutions, including measuring a number of time-related quantities, counting events or totalizing, and monitoring position with quadrature encoders. You can also use counter/timers to generate pulses and pulse trains. Counter/timers often fulfill critical timing functions as components of complex measurement systems [6].

The NI 660x counter/timers use the NI-TIO, a National

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Instruments ASIC chip specifically designed to meet the counting and timing requirements of measurement applications that are beyond the capabilities of off-the-shelf components. The wider functionality and simple programming interface make the NI 660x your best choice for counting and timing applications. Example applications include frequency measurement, position measurement, generation of retriggerable pulses, frequency shiftkeying, two-signal edge separation measurements, continuous buffered event counting, and continuous buffered pulse train measurements. The NI 660x counter/timer devices are readily integrated into measurement systems that require synchronization across multiple hardware devices because they are equipped with the National Instruments PXI trigger bus or the RTSI bus [5, 7]. In addition to counter/timer functionality, the NI 660x products include TTL/CMOS-compatible digital I/O ports that are bit configurable for input or output.

Data acquisition begins with the physical phenomenon to be measured. This physical phenomenon could be the temperature of a room, the intensity of a light source, the pressure inside a chamber, the force applied to an object, or many other things. An effective DAQ system can measure all phenomena. A transducer is a device that converts a physical phenomenon into a measurable electrical signal, such as voltage or current. The ability of DAQ system to measure different phenomena depends on the transducer to convert the physical phenomena into signals measurable by the DAQ hardware. Transducers are synonymous with sensors in DAQ systems [8]. There are specific transducers for many different applications, such as measuring temperature, light, pressure, or fluid flow as illustrated in table (1).

In order to get data from the running experiment, correctly make input and output signal connections is very important. A correct connection is shown in Figure (4). Before starting to do any connection, pin code for PCI6602 and the connector block are required. The electrical connections for the counters are as shown in table (2).

IV. PHOTON EXISTENCE PROBABILITY CALCULATION

Second order correlation function is known as the intensity correlation function or the second order coherence function. It is defined by [9]:

$$g^2(t) = \frac{\langle I(t)I(t+t) \rangle}{\langle I(t) \rangle^2} = \frac{\langle a^*(t)a(t)a^*(t+t)a(t+t) \rangle}{\langle a^*(t)a(t) \rangle^2} \quad (1)$$

where I are the intensities.

The probability function (g^2) can be used to describe the photon correlation and the quantum properties of light. Theoretically, one could use a fast photon counter with zero dead time, or the ability to count multiple photons to measure g^2 directly. In actual experiment, a hardware setup is needed to show the correlation between two fluctuating currents by recording and analyzing the product of the currents. The Connection on the connector block and also the number of the device. Other parameters need to be set are the initial counts, count direction, and type of edge.

beam splitting ratio and the losses in the two arms do not matter.

At very low intensities, the photo detector becomes a photon counter. For a photon counter, the probability of count is proportional to the intensity of light. In this case, g^2 is expressed in terms of the photon number at the two counters as:

$$g^2(t) = \frac{P_{BB'}}{P_B P_{B'}} \quad (2)$$

where P_B ($P_{B'}$) is the probability of a detection at detector B (B') in a time interval Δt , and $P_{BB'}$ is the probability of making detections at both B and B' in the same time interval (coincidence). However the probabilities can be expressed in term of measured counts rates. The probability of detection at B in a short time interval Δt is simply given by the average rate of detections, multiplied by Δt . The average rate of detections at B is just the number of detections N_B divided by the counting time T that we are averaging over. The probabilities for B detection and BB' coincidences are given similarly:

$$\begin{aligned} P_B &= \left(\frac{N_B}{T} \right) \Delta t \\ P_{B'} &= \left(\frac{N_{B'}}{T} \right) \Delta t \\ P_{BB'} &= \left(\frac{N_{BB'}}{T} \right) \Delta t \end{aligned} \quad (3)$$

Substituting this into equation (2), we get

$$g^2(t) = \frac{N_{BB'}}{N_B N_{B'}} \left(\frac{T}{\Delta t} \right) \quad (4)$$

Where B, B' and BB' are counter 1, counter 2 and counter 3 respectively.

The flowchart and SubVI block for g^2 calculation are shown in Figure (5). When this program starts, first thing to be done is to set the counter setting. Three independent counters are needed in this program. For each counter, the input/output has to be set according to the conn A labVIEW program is developed which will be used to count the number of photons in the light when we specified the counter that we are using and the device number. The counter number should be specified according to the pin connector assignments that can be found in the manual of data acquisition card that is been used. Input must be connected to the correct pin and should specify the correct counter number in LabVIEW to get the output. Connection can checked using measurement and automation software. Figure (6) shows the virtual instrument (VI) that has been created to count photons in the light; before we run the program we must set the counter number.

The buffer of the computer records data collected from detector 1, detector 2 and also coincidence counter 3 from the source. These data will be sent to g^2 function SubVI to

calculate the probability of the detected photons. Finally, the program will stop after counting all the points. These data will be saved in a file. Figure (7) shows the block diagram of the main program using LabVIEW.

V. SOFTWARE DESIGN

A labVIEW program is built to be used for counting a number of photons in the light when the counters and device number are initialized. The counter number should be specified according to the pin connector assignments, which can be found in the manual of data acquisition card that is used. Input must be connected to the correct pin and should specify the correct counter number in LabVIEW to get the output. Connection can be checked using measurement and automation software. Figure (6) shows the front panel of the Virtual Instrument (VI) program that counts photons existence in the light. While table (3) shows the probability of the photons existence depending on the number of photons detected in the light for fixed time interval and counting period equal to 5000 s.

VI. CONCLUSION

The LabVIEW based DAQ system is used to prove the

existence of the photons in the light. The facilities of the NI-PCI 6602 data acquisition card (Timer/Counter) are used for counting the number of photons.

REFERENCES

- [1] Holbrow, C. H., E. J. Galvez, and M. E. Parks. 2002. Photon quantum mechanics and beam splitters. *Am J Phys* 70: 260 – 265.
- [2] N. Kehtarnavaz, N. Kim, and I. Panahi, Digital signal processing system design using LabVIEW and TMS320C6000, IEEE Digital Signal Processing Workshop, 2004.
- [3] Chance Elliott, Vipin Vijayakumar, Wesley Zink, and Richard Hansen: National Instrument LabVIEW: A programming environment for laboratory automation and measurement, The association for Laboratory Automation, 2007.
- [4] A. P. French and Edwin F. Taylor, Introduction to Quantum Physics ~Chapman and Hall, London, 1974, pp. 231–278.
- [5] D. F. Styer, The strange world of quantum mechanics ~cambridge U.P., New York, 2000.
- [6] National Instruments, DAQ 6023E/6024E/6025E, user manual: January 1999 Edition.
- [7] www.instrumentation-central.com.
- [8] National Instruments, DAQ 6023E/6024E/6025E, user manual: January 1999 Edition.
- [9] www.ni.com.

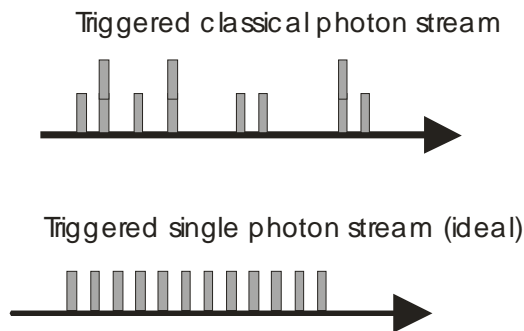


Figure (1): A pulsed classical source (top) and a pulsed single photon source (bottom).

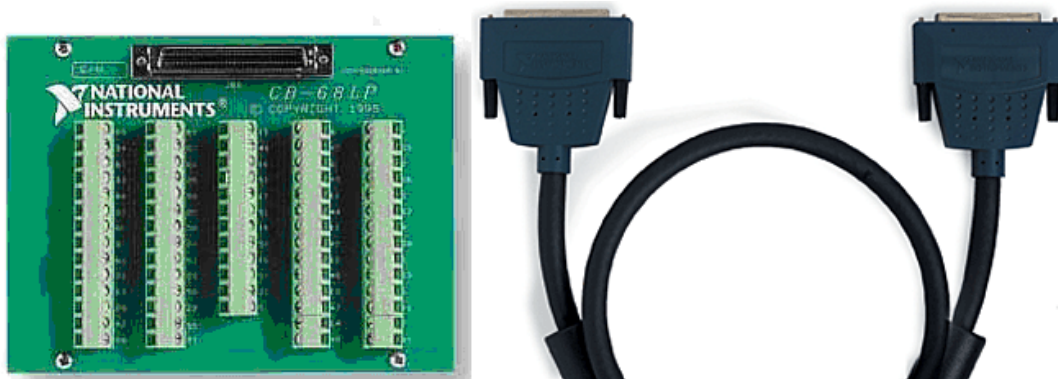


Figure (2): CB-68LP and also shielded cable.

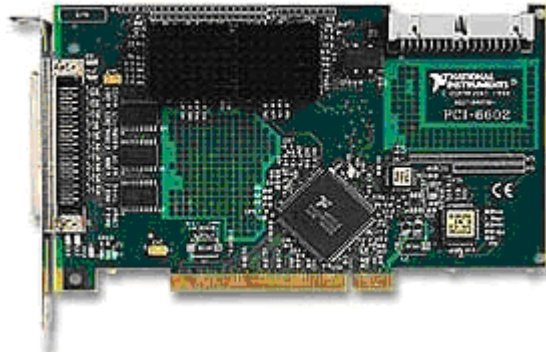
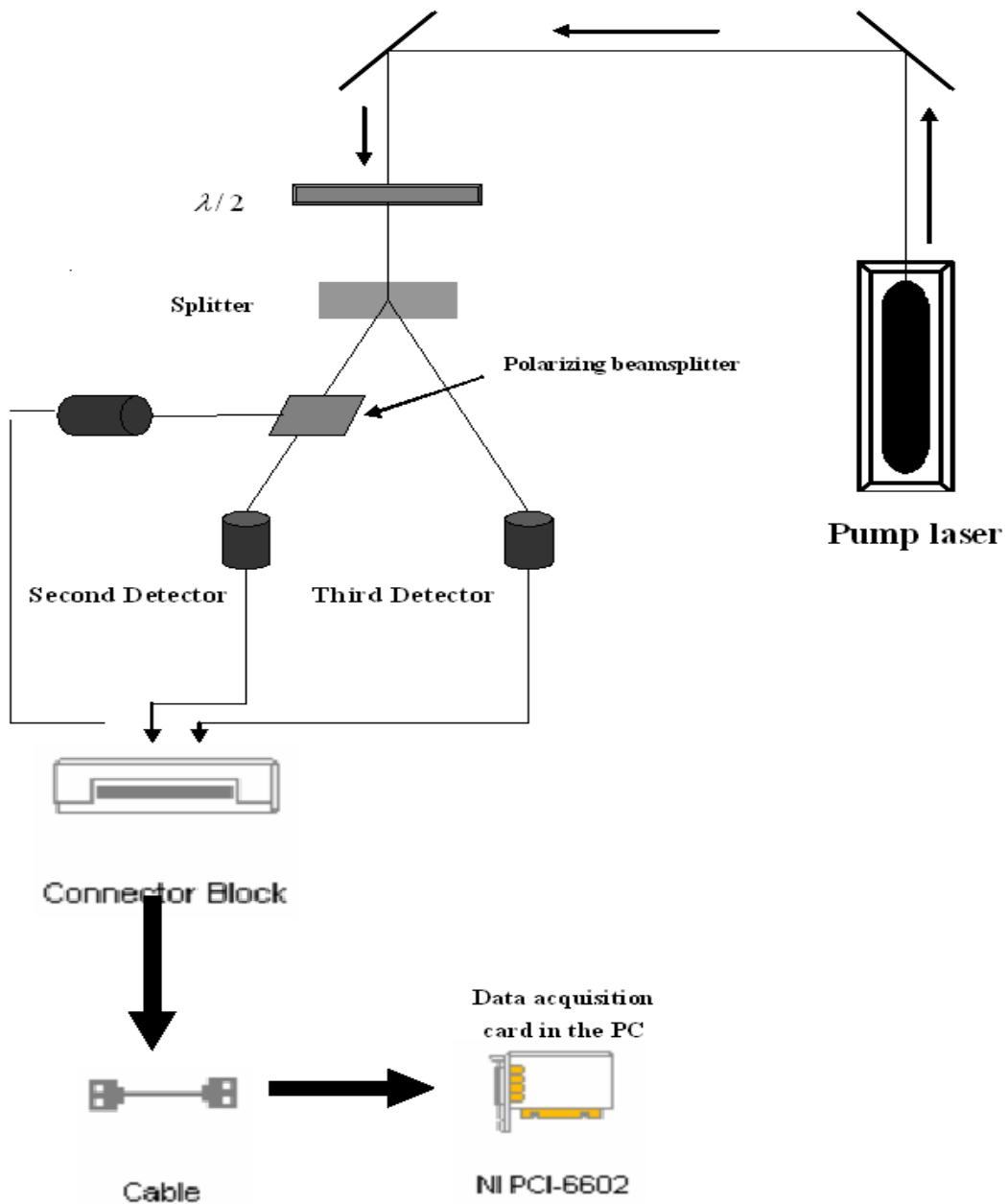


Figure (3): Counter / timer Data Acquisition Card.



Figure(4):The setup of the Data Acquisition (DAQ) for photons detection in the light.

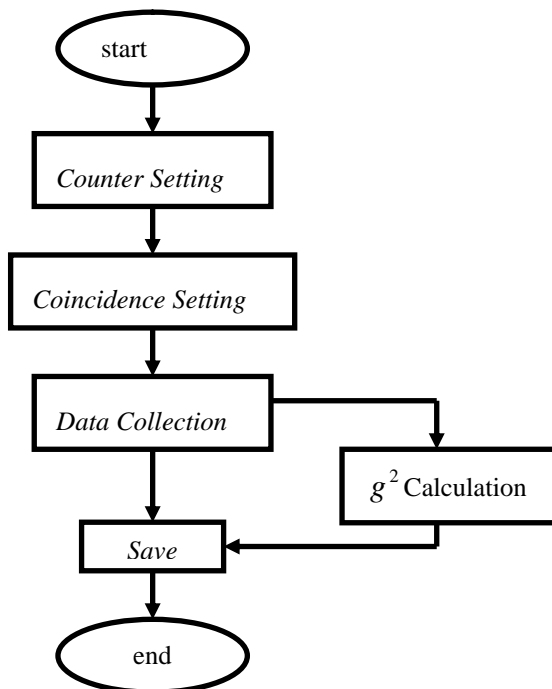


Figure (5): Flowchart for probability calculation.

TABLE (1): SHORT LIST OF SOME COMMON TRANSDUCERS AND THE PHENOMENA THEY CAN MEASURE.

Phenomena	Transducer
Temperature	Thermocouples Resistive temperature device (RTDs) Thermistors
Light	Vacuum Photo sensors
Sound	Microphone
Force and pressure	Strain gauge Piezoelectric transducers
Position and displacement	Potentiometers Linear voltage differential transformer Optical encoder
Fluid	Head meters Rotational flowmeters
pH	pH electrodes

TABLE (2): ELECTRICAL CONNECTION FOR THE COUNTERS.

Description	Counter No.	Programmable Function Input (PFI)
Detector 1	0	39
Detector 2	1	35
Coincidence 3	2	31
Ground	-	36

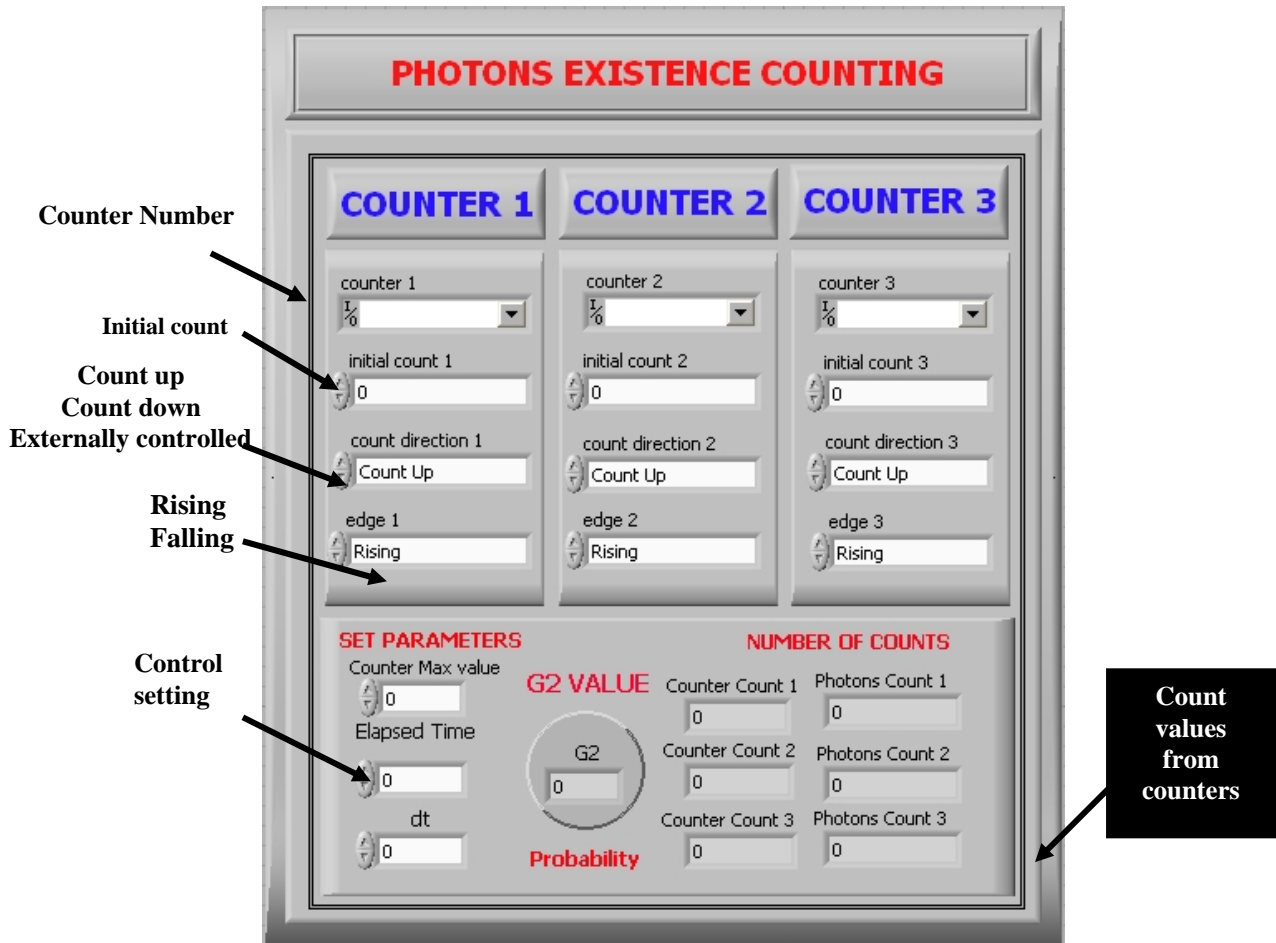


Figure (6): Front Panel of virtual instrument.

TABLE (3): PROBABILITY CALCULATION USING THREE COUNTERS WITH COUNTING TIME = 5000 S

	Counter 1(<i>B</i>)	Counter 2(<i>B'</i>)	Counter 3(<i>B''</i>)	Probability (g^2)
$\Delta T = 1000$	310	310	450	0.0234
$\Delta T = 1000$	500	500	700	0.014
$\Delta T = 1000$	1300	1300	2800	0.0082
$\Delta T = 1000$	3050	3050	6500	0.00349

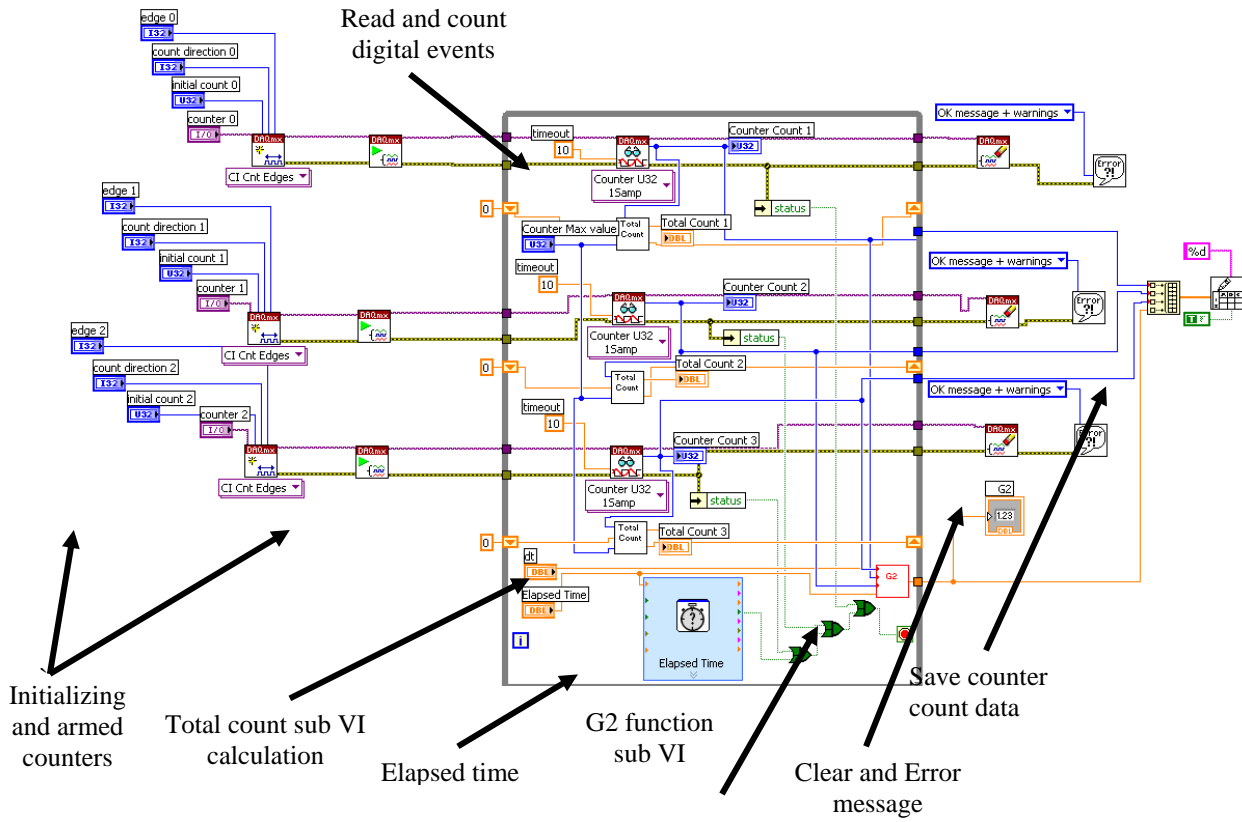


Figure (7): Block diagram of the counting multiple digital events.