# CC1 - Handheld

# Coincidence Counter

# USER'S MANUAL

Rev. 1.03



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# Contents

# Principle of Operation

## 1.1 Overview

The CC1 is a low-cost, handheld coincidence counter intended for use with single photon counting experiments. The unit can detect and count TTL electrical pulses with nanosecond resolution and a maximum count value of 2,097,152 pulses per channel. Pulses that occur simultaneously on Channel 1 and Channel 2, within a specified “coincidence window,” are treated as “coincident” pulses and are measured and displayed by the unit (max coincidence count equal to 2,097,152).

An LCD display on the front of the unit allows easy viewing of all measured single and coincidence counts. This display, in addition to the push buttons on the front of the unit, provides a simple interface for displaying results and setting up measurements. A USB connection on the side of the unit provides power to the system while also allowing for optional serial control of the device by a computer.

The CC1 comes pre-programmed with all of the functionality described in this manual; however, it is capable of much more. The unit contains both a re-programmable microprocessor (for handling the user interface and serial communications) and a re-programmable FPGA (for handling high-speed pulse counting). Both of these devices can be programmed by the user to implement a wide range of features.

In the Appendix section, the user will find the necessary documentation for programming the CC1 for custom applications. Whether it is implementing a time histogram recorder, expanding/modifying the existing features of the CC1, or developing a custom device for use in implementing new cryptographic protocols, the CC1 is a flexible platform that will greatly simplify and speed your development effort.

## 1.2 What is Included

The CC1 Handheld Coincidence Counter ships with the following materials:

a) 2m USB cable (USB-B)
b) CC1 Coincidence Counter
c) USB-to-AC power module

The various components (with their respective labels) are shown in Figure 1 on the following page.


A B C

*Figure 1. Components included with CC1 Coincidence Counter.*

### 1.3 Powering the Unit and Connecting Inputs

The CC1 is powered through its USB port. The USB cable provided with the system should be plugged into the side of the unit as shown in Figure 2.

*Figure 2. Power over USB connection.*

The other end of the USB cable can be plugged into a computer USB port or plugged into the included USB-to-AC power connector, as shown in Figure 3.

*Figure 3. USB-to-AC Adapter.*

Once powered, the CC1 will display a startup screen for five seconds on the unit's blacklit LCD. The unit's "Count Screen" will then be displayed as shown in Figure 4.

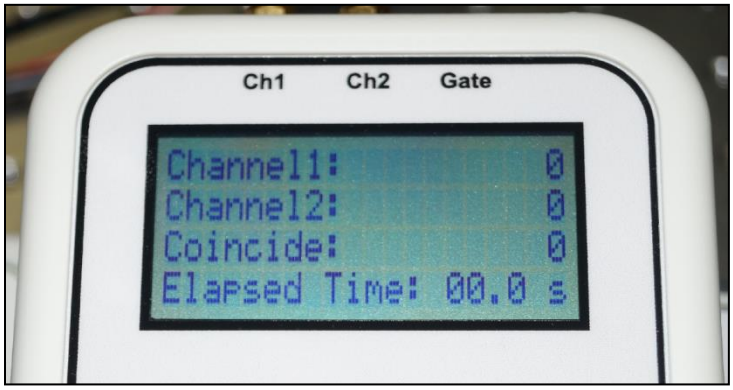


*Figure 4. Count Screen on startup.*

To connect signals to the CC1, three SMA connector jacks are available at the top of the unit. To detect coincident pulses, Channels 1 and 2 must both be connected to a pulse signal. If the counting of single and coincidence pulses should be gated (see next section for more details), then the third channel ("GATE") should be connected to the associated gate pulse.

### 1.4 Navigating the Menus

The CC1 has six buttons on its front face. The buttons, along with signal connectors and peripheral ports, are shown in Figure 4.

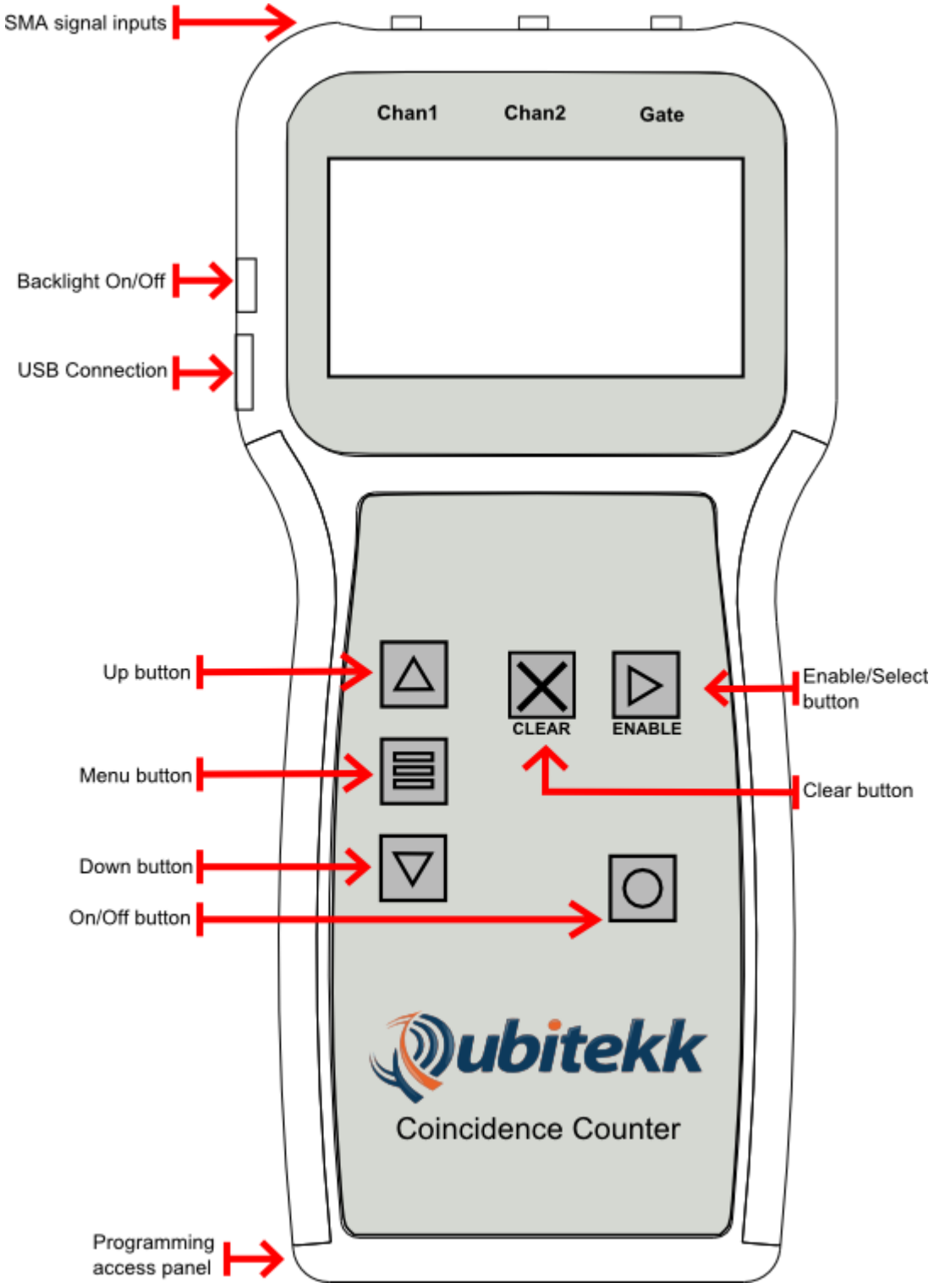


*Figure 4. CC1 Buttons and Ports.*

To configure the CC1 for a measurement, press the "menu" button. The CC1's Menu Screen will be displayed as shown in Figure 5.

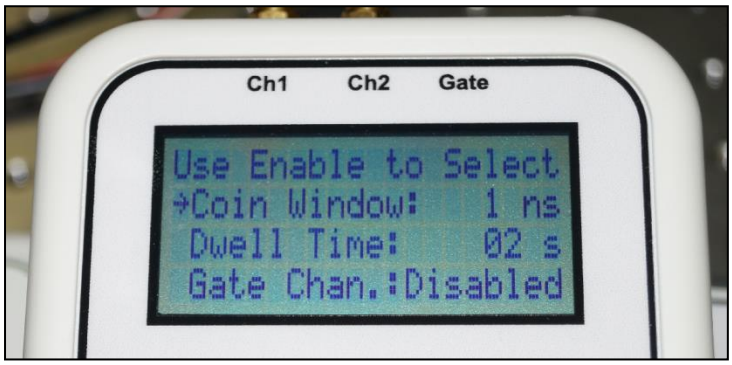


*Figure 5. Menu Screen.*

Pressing the "menu" button again will return the user back to the Count Screen.

The Menu Screen contains six settings that can be changed by the user. These settings will be covered in the following section. The various settings can be viewed by scrolling up or down in the menu using the "UP" and "DOWN" arrow buttons.

When a setting needs to be changed, the setting can be selected for modification by pressing the "ENABLE" button. The setting value will blink, indicating that it is ready for modification. Again, the UP" and "DOWN" arrow buttons can be pressed to change the setting value. Once complete, press the "ENABLE" button again to continue scrolling through the menu.

### 1.5 Setting Up a Measurement

Prior to any measurement, the measurement parameters for the CC1 should be configured. The next section of the manual will describe each parameter and discuss their impact on the measurement. The default settings for the CC1 (upon power up) are shown in Table 1 below:

| Setting | Value |
|---|---|
| Coincidence Window | 1 ns |
| Dwell Time | 2 s |
| Gate Chan. | Disabled |
| Subtract Acc.? | No |
| Trigger | Start/Stop |
| CH1 Delay | 0 ns |
| Firmware Ver | 2.001 |

## 1.6 Making a Measurement

Once all measurement settings have been adjusted, the “menu” button should be pressed to return to the Count Screen. With the Count Screen displayed, press the “ON/OFF” button to start or end a count.

Once the “ON/OFF” button has been pressed, the details of the count measurement will be displayed on the LCD as shown in Figure 6.

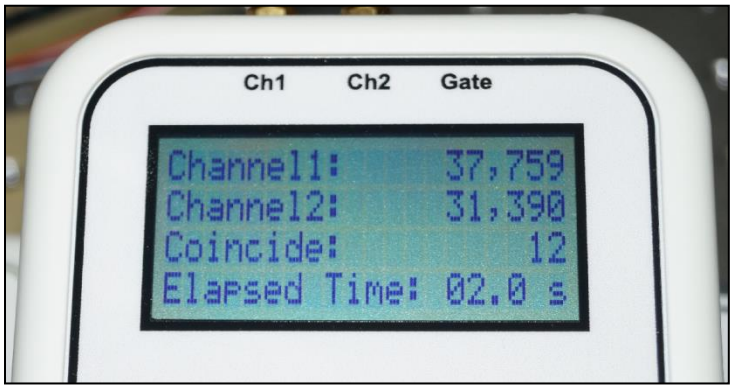


*Figure 6. Count Screen after measurement.*

Once the measurement is complete, the counts will remain on the screen until a new count is initiated.

*NOTE: If the unit is being triggered in “Continuous” mode, the counts will only remain on the screen for a short period of time before resetting to zero and beginning the next count.*

# Settings

## 2.1 Description of Counting Process

Pulses detected on Channel 1, Channel 2, and the optional Gate channel will be counted as coincident pulses based on a number of settings made prior to the measurements. In general, the simplest measurement of coincidence is as shown in Figure 7:

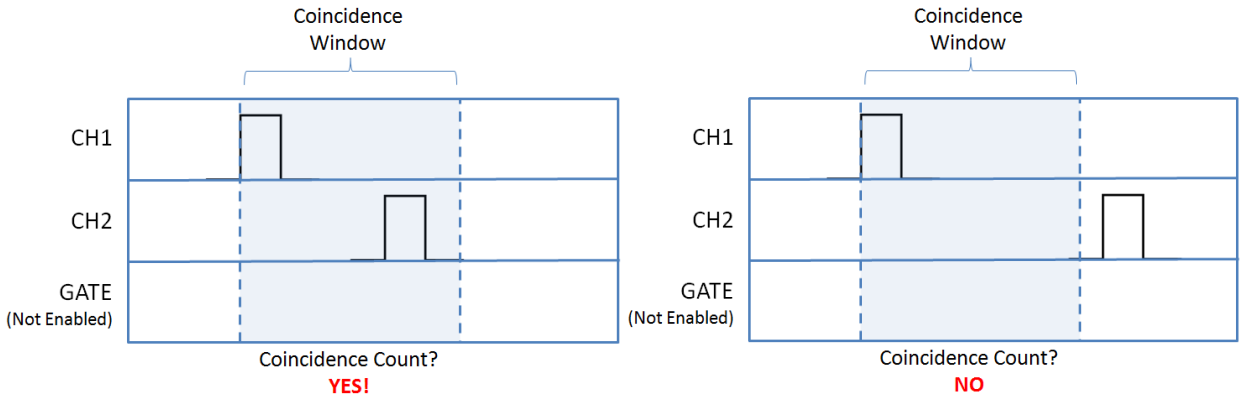


*Figure 7. Simple coincidence measurement described.*

Two pulses will be counted by the CC1 to be coincident if:

a. The time between the rising edges of the two pulses is less than the coincidence window

If the GATE signal is enabled, then the two pulses will only be counted by the CC1 as coincident if the following two conditions are satisfied:

a. The time between the rising edges of the two pulses is less than the coincidence window
b. The GATE signal is enabled during both rising edges

Figure 8 represents a coincidence measurement with the GATE signal enabled.

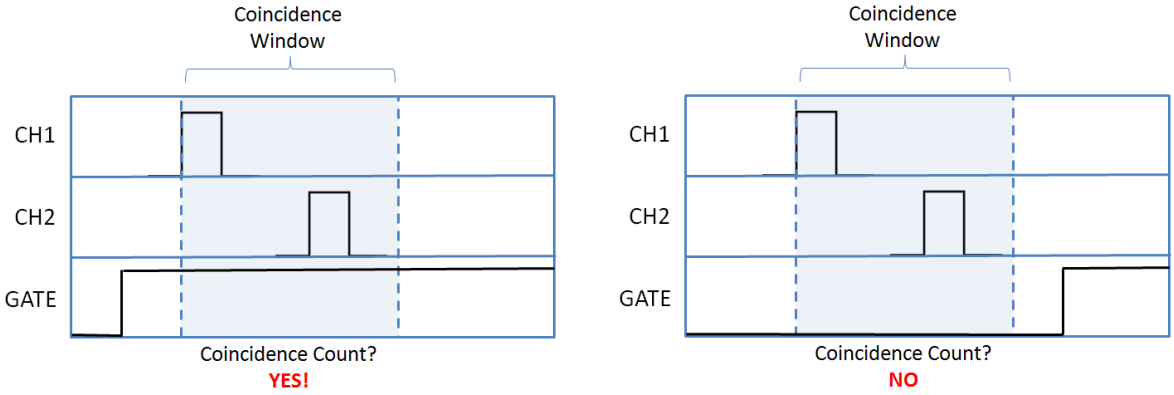


*Figure 8. Coincidence measurement with a GATE signal.*

With this understanding in place, the remainder of this section will look at how aspects of this measurement are specified in the CC1.

### 2.2 Coin Window

If pulses are simultaneously detected within some short time window, then they are said to be coincident. The CC1 refers to this time window as the Coincidence Window, or “Coin Window” for short. Technically, the Coin Window is the maximum allowed time between the rising edge of a pulse on Channel 1 and a pulse on Channel 2 before two pulses are no longer considered to be coincident.

The Coin Window can be set on the CC1 to be any integer value between 1 and 8 nanoseconds.

### 2.3 Dwell Time

The Dwell Time is the amount of time to accumulate pulses. For example, if the Dwell Time is 20 seconds, then all single pulses detected on Channel 1 during a 20 second measurement period would be totaled and displayed. This would also be true for Channel 2 and the coincident channel.

The Dwell Time can be set on the CC1 to values ranging between 0.1 second and infinity. When a measurement is initiated, the CC1 will accumulate counts for an amount of time equal to the Dwell Time. If the Dwell Time is infinity, the CC1 will accumulate counts indefinitely or until the ON/OFF button is pressed and the count process stopped.

### 2.4 Gate Chan.

The Gate Chan. setting determines whether or not the GATE channel performs any function. If the Gate Chan. value is set to “ENABLED,” single and coincidence counts will only be detected when the GATE signal is high. If the Gate Chan. value is set to “DISABLED,” the GATE signal will be ignored.

### 2.5 Subtract Acc.?

In some experiments, the CC1 may be used to measure coincidence counts to identify correlations between signals. Coincidence counts can often indicate the presence of some shared source of photon generation or optical phenomena. However, coincidence counts can also be the results of random chance.

Statistically, there is some probability that a random stream of pulses on Channel 1 will occasionally produce a pulse that is coincident with another random stream of pulses on Channel 2. This statistical likelihood is called the “accidentals” and it can be calculated using the following formula:

$$\text{Accidentals} = \frac{2(\text{Coincidence Window(sec)})(\text{Channel\#1 Singles})(\text{Channel\#2 Singles})}{\text{dwell time (sec)}}$$

Because accidentals can sometimes obscure the true correlations being sought in an experiment, it can be advantageous to have these accidentals automatically calculated and subtracted from the measured coincidence value.

The Subtract Acc.? setting allows the user to turn this calculation on or off. If the Subtract Acc.? value is set to “YES,” then the estimated accidentals will be calculated and subtracted from all coincidence measurements. If the Subtract Acc.? value is set to “NO,” then the full coincidence counts (with accidentals included) will be reported.

### 2.6 Trigger

The Trigger setting allows the user to select how a measurement will be started and stopped. If the Trigger setting is set to “Continuous,” then the measurements will start once the ON/OFF button is pressed. Once a count is initiated, the unit will accumulate counts for the set Dwell Time. Once the Dwell Time has been reached, the total counts accumulated will be shown on the counter’s display for a short period of time. Then the unit’s counters will automatically be reset and a new count initiated. This cycle will continue over and over until the ON/OFF button is again pressed to halt continuous triggering.

If the Trigger setting is set to “Start/Stop” then a new count will be initiated only when the ON/OFF button is pressed. Once a count is started, the count will continue until either the dwell time is reached or the ON/OFF button is pressed again to stop the counting cycle.

### 2.7 CH1 Delay

The signal coming into the Channel 1 connector can be delayed by adjusting the “CH1 Delay” setting. Adding a delay to a channel can be useful when searching for coincident events in signals that may be delayed. For example, if the cable from one photon detector is one meter long while the cable from a second photon detector is two meters long, then there will be a transmission delay of roughly 5 ns that must be subtracted to detect coincident events.

The CH1 delay setting allows delays of 0, 2, 4, 6, 8, 10, 12, and 14 ns to be programmed into the CC1.

### 2.8 Firmware Ver.

The firmware version is a four digit identifier of the CC1’s firmware release version. This setting cannot be changed by the user.

# Serial Interface

## 3.1 Serial Interface Setup

The CC1 has an emulated COM port for serial communication, and uses SCPI-compliant commands. To use the serial interface, use the included USB-B 2m cable to connect the CC1 to a computer USB port. The USB cable allows the CC1 to both receive power and send data over the USB connection.

To communicate with the CC1, download a serial terminal emulator program (such as RealTerm or PuTTY on Windows) or send serial commands through your own custom program. The serial interface settings should be configured with the following settings:

| Setting | Value |
|---|---|
| Baud Rate | 19200 bps |
| Data bits | 8 |
| Parity | None |
| Stop Bits | 1 |
| Flow Control | None |

## 3.2 Commands

The following serial commands can be used to control/interface the CC1 unit with a computer or microcontroller. If a command is not recognized, the CC1 will reply with “Unknown Command.”

| Command | Description |
|---|---|
| COUN:C1? (:C2?)(:CO?) | Returns the current value on the counter, either Channel 1 (C1), Channel 2 (C2), or Coincidences (CO) |
| :CLEA | Sends the clear signal to the counters |
| :DELA N | Set the delay value (in nanoseconds) on Channel 1. N may be 0, 2, 4, 6, 8, 10, 12, or 14ns. |
| :DELA? | Returns the delay value on Channel 1 in nanoseconds |
| :DWEL N | Sets the dwell time to N seconds. N must be equal to or greater than 0.1 and cannot be more than 5 characters long (including the decimal point). |
| DWEL? | Returns the dwell time in milliseconds |
| FIRM? | Returns the firmware release identifier |
| :GATE N | Sets whether or not the GATE channel is enabled: 0 = No, 1 = Yes |
| GATE? | Returns whether or not the GATE channel is enabled: 0 = No, 1 = Yes |
| :SUBT N | Sets whether or not to subtract accidentals from coincidence rate: 0 = No, 1 = Yes |
| SUBT? | Returns value indicating if accidentals are being subtracted from coincidences: 0 = No, 1 = Yes |
| :TRIG N | Sets the trigger value: 0 = Continuous, 1 = Start/Stop |

| Command | Description |
|---|---|
| TRIG? | Returns the value of the trigger setting: 0 = Continuous, 1 = Start/Stop |
| :WIND N | Sets the coincidence window length to N nanoseconds. N must be between 1 and 8. |
| WIND? | Returns the coincidence window length in nanoseconds |

### 3.3 Sample Serial Program

The following sample program (written in Visual Basic 6.0) provides a very simple example of how serial commands can be used through third-party programs to control the CC1:

```
MSComm3.PortOpen = True                          ‘Open COM Port

'-- Prepare Coincidence Counter for Measurements --
MSComm3.Output = ":GATE 0" & Chr$(13)            ‘Disable GATE Channel
Sleep 300                                        'Wait 0.3 seconds for command to transfer
MSComm3.Output = ":SUBT 0" & Chr$(13)            'Turn off Subtract Accidentals option
Sleep 300                                        'Wait 0.3 seconds for command to transfer
MSComm3.Output = ":TRIG 1" & Chr$(13)            'Set Trigger Option to Start/Stop
Sleep 300                                        'Wait 0.3 seconds for command to transfer
MSComm3.Output = ":DWEL 20000" & Chr$(13)        'Set Dwell Time to 20 seconds
Sleep 300                                        'Wait 0.3 seconds for command to transfer
MSComm3.Output = ":DELA 2" & Chr$(13)            'Set Delay Time on Channel 1 to 2ns
Sleep 300                                        'Wait 0.3 seconds for command to transfer
MSComm3.Output = ":WIND 3" & Chr$(13)            ‘Set Coincidence Window to 3 ns
Sleep 300                                        'Wait 0.3 seconds for command to transfer

'-- Take Measurement --
MSComm3.Output = ":COUN:ON" & Chr$(13)

dt = Now                                         ' Wait for Dwell Time (plus 1 second)
Do While DateDiff("s", dt, Now) < 21
    DoEvents()
    Sleep 50                                     'Put app to sleep in small increments
Loop

'--Transfer Measurements --
MSComm3.Output = "COUN:C1?" & Chr$(13)           ‘Query Channel 1 Counts
Sleep 300                                        'Wait 0.3 seconds for command to transfer
Textbox1.text = MSComm3.Input                    ‘Display counts in a textbox
MSComm3.Output = "COUN:C2?" & Chr$(13)           ‘Query Channel 2 Counts
Sleep 300                                        'Wait 0.3 seconds for command to transfer
Textbox2.text = MSComm3.Input                    ‘Display counts in a textbox
MSComm3.Output = "COUN:CO?" & Chr$(13)           ‘Query Coincidence Counts
Sleep 300                                        'Wait 0.3 seconds for command to transfer
Textbox3.text = MSComm3.Input                    ‘Display counts in a textbox

MSComm3.PortOpen = False                         ‘Close COM Port
```