

# Measuring Frequency Using Counters

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## Instructor's Portion

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### Summary

The objective of this lab is to provide the students with hands on experience in measuring the frequencies of digital signals using general-purpose counters available in the PCI 1200 data acquisition card. For this purpose, the students will use ready-made VIs available with the LabVIEW sample files. The lab assumes that the students have prior exposure to LabVIEW, and that they are familiar with the basics of writing and debugging LabVIEW VIs (Virtual Instrument). The students should study the theory section of this experiment before coming to the lab.

### Uses

This experiment applies to general instrumentation and electronics systems interfacing courses in electrical engineering or engineering technology programs. The experiment can also be useful in basic LabVIEW courses, teaching the concepts of general-purpose counters and frequency measurement.

### Equipment List

- PC running MS Windows  
(visit [http://www.ni.com/labview/lv\\_sysreq.htm](http://www.ni.com/labview/lv_sysreq.htm) for requirements specific to your operating system)
- LabVIEW Full Development System
- PCI 1200 DAQ from National Instruments (part number 777386-01)
- CB-50LP I/O Connector Block from National Instruments (part number 777101-01)

- NBI Ribbon Cable from National Instruments (part number 180624-10)
- 7404 Hex Logic Inverter from National Semiconductor (datasheet available at: <http://www.fairchildsemi.com/ds/DM/DM7404.pdf> )
- Tektronix TAS475 Four Channel Oscilloscope, or any general lab scope with 2 or more channels.
- HP 3312A Function Generator, or any general-purpose function generator with sinusoidal and square output signals of variable frequency.

## Setup

Follow the steps listed below to prepare the workstation for this experiment. The instructions assume you are using the equipment list shown previously.

**Note:** Most of the manuals that are referred to ship with National Instruments hardware and software. If you can't find your hardcopy of the manuals, you can get them online at <http://www.ni.com/manuals>. If you encounter problems during setup, contact technical support at <http://www.ni.com/support>.

### Before the Day of the Lab

1. Install LabVIEW (see the *LabVIEW Release Notes* for your version of LabVIEW).
2. Install your PCI-1200 board (see the *PCI1200 User Manual*, or online at: <http://sine.ni.com/apps/we/nioe.vp?cid=5497&lang=US>).
3. Connect the ribbon cable to the PCI1200 card and to the I/O connector block.

### On the Day of the Lab

1. Power up the computer.
2. Start LabVIEW.
3. Power up the function generator.

## References

- NI's web site: <http://www.ni.com>

- PCI 1200 user's manual from NI. Available online at:  
<http://sine.ni.com/apps/we/nioc.vp?cid=5497&lang=US>
- 8254 Programmable Interval Timer datasheet from Intel. Available online at:  
<http://support.intel.com/support/controllers/peripheral/231164.htm>

## Student's Portion

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### Introduction

In this experiment, you will use ready-made LabVIEW VIs available from the LabVIEW sample files to count the pulses and measure the frequency of a digital signal using the General Purpose Counters of the PCI 1200 Data Acquisition Card (DAQ). This lab requires background in counters and frequency measurement. These concepts are summarized in the Theory section of this experiment.

### Objective

- To learn how to use LabVIEW to count pulses and measure frequencies using digital hardware counters.
- To learn about the general purpose counters of data acquisition cards.

### Theory

#### **The 8254 Timer/Counter <sup>1</sup>**

The 8254 is a digital counter/time chip that has the capabilities of counting waveform pulses. The chip can also be used through its square-wave generating capability to determine the unknown length of a pulse as compared to a known clock frequency.

The 8254 Timer/Counter has three independently programmable and functional 16-bit counters. Each of these counters is capable of handling clock frequencies up to 12MHz, depending on the make of the chip. The 82C54 can handle 8MHz, the 82C54-10 can handle 10MHz, and the 82C54-12 can handle 12MHz.

This chip has six modes of operation that allow it to function as an event timer, an elapsed time indicator, a programmable one-shot, or a square wave generator.

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<sup>1</sup> 8254 Programmable Interval Timer datasheet from Intel

*Mode 0: Interrupt on Terminal Count* makes the chip count down from a pre-defined value and when count reaches a value of zero, the output of this counter goes logic high thereby allowing it to be used as an interrupt signal.

*Mode 1: Hardware Retriggerable One-Shot* also makes the chip count down except that the count value can be reset at any time through the gate. When count reaches zero, the output goes logic high and remains high until counter is retriggered. The advantage of this mode is that the count value does not have to be loaded every time the count is reset.

*Mode 2: Rate Generator*, makes the counter count down from a predefined value. When the count is decremented to 1, the *out* pin goes low for one clock pulse, then goes high again and count reinitiates from the previous count value. In this mode, *gate* does not reset the counting value like in mode 1; logic high is the state that the *gate* should be in for normal counting. A logic low on the *gate* pauses the counting sequence until it is returned to logic high.

*Mode 3: Square Wave Mode* is used to create a baud rate. This mode allows a user to create a square wave of a known frequency. The initial count is divided by two. The first half of the count sets the out logic high. The second half of the count sets the out logic low.

*Mode 4: Software Triggered Mode*, is another mode for counting down. This mode's countdown sequence is commenced by loading the initial count value. This one-start sequence is what makes this mode software programmable.

In *Mode 5: Hardware Triggered Strobe (Retriggerable)*, countdown is triggered by the rising edge of the gate and will expire N+1 clock pulses.

The counter available in the PCI 1200 card is 8253C, which is very similar to 8254. Both chips have the same specs, but different packaging and pin assignment. The three counters in the 8253C on PCI1200 are available for general timing functions such as clock output, pulse output and event counting. One of those counters has a built in 20MHz source clock.

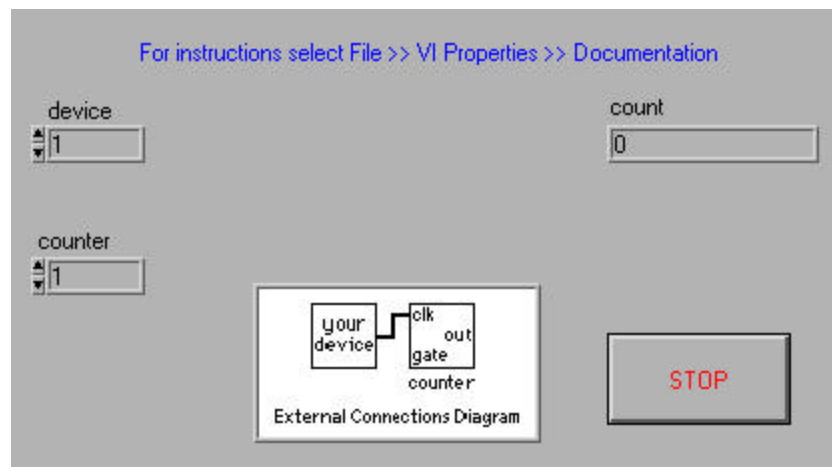
### **LabVIEW Frequency Measurement VIs**

Figures 1 and 2 show the front panel of the VIs used in this experiment. Both of them are provided by National Instruments as a sample in LabVIEW Full Development System. These sample VIs are found within the *8253.llb* samples library.

The first VI is titled *Event Counter*, and it is an example program which is used to count electrical pulses. In this lab, the VI is going to be used to count the pulses generated by a function generator and observe the counting capabilities of LabVIEW and the 8253C chip. The front panel of

this VI can be seen below in Figure 1. The controls and indicators of this VI are explained as follows:

1. *Device*: This control is used to specify which National Instruments hardware device is being used by the VI program. For this lab, the device 1 refers to the installed PCI 1200 board.
2. *Counter*: This control is used to specify which of the three counters, from the 8253C chip, is being utilized by the VI program. This value can be 0, 1, or 2.
3. *Count*: This indicator shows the number of pulses that the 8253C chip has counted.

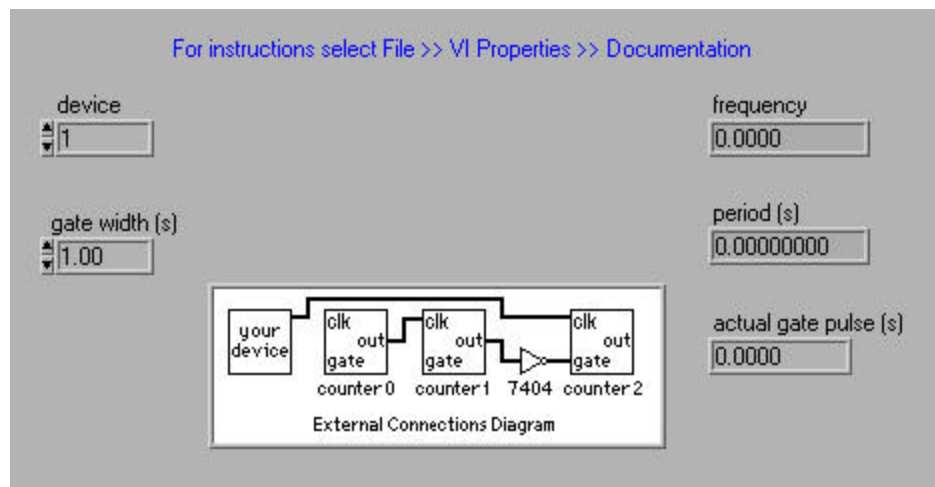


**Figure 1. Front Panel of: Count Events VI**

The second VI used is titled *Measure Low Frequency*, and it is also an example program which is used to count electrical pulses. The difference is that this VI is aimed at using the counters to estimate a waveform's frequency. This VI counts the pulses of a waveform of an unknown frequency while using a second waveform of a known frequency to determine the period of sampling for the first waveform. To achieve accurate results, the frequency of the unknown waveform must be much faster than the frequency of the second waveform. To find the unknown frequency, the VI counts the number of pulses generated within one period cycle of the known waveform's frequency. The front panel can be seen below in Figure 2. The controls and indicators of this VI are as follows:

1. *Device*: This control is used to specify which National Instruments hardware device is being used by this VI program. For this lab, the device 1 refers to the PCI 1200 board.

2. *Gate Width (s)*: This is a control of the time-window used for counting pulses. It is specified in seconds.
3. *Frequency*: This indicator displays an estimate of the frequency pertaining to the waveform under test.
4. *Period (s)*: This indicator displays an estimate of the period, in seconds, pertaining to the waveform under test.
5. *Actual Gate Pulse (s)*: This is an indicator of the actual time-window used by the vi program for counting pulses. It is specified in seconds.



**Figure 2. Front Panel of: Measure Low Frequency vi**

## Pre-Lab Preparation

Read this experiment before coming to the lab. You should understand the theory of digital timers and counters, as explained in the theory section of this experiment.

Bring the following to lab with you:

- This experiment.
- Your lab notebook and pencil.
- 2 virus-free formatted 3.5-inch floppy disks (always make a backup copy of your code on the second disk).

Answer the following questions in the datasheet provided at the end of this experiment *before* coming to the lab. Remember to include these answers in your lab report.

1. Which device in PCI 1200 card is used for frequency measurement?

2. What are the pins of any of the counters used in PCI 1200? What pin configuration is used to enable the counter?
3. Which VIs from LabVIEW samples measures frequency? And which ones counts digital pulses? And which one measures extremely low frequencies.
4. How do we relate pulses width and frequency?

## Workstation Details

Your workstation should have the following items:

- Computer with National Instruments LabVIEW software
- National Instruments DAQ board (inside the computer)
- National Instruments DAQ board terminal block
- Tektronix Oscilloscope
- HP Function Generator

## Lab Procedure

1. Open the *Count Events* VI. The front panel is shown in Figure 1.
2. Connect the function generator to the Clk input of counter 1 and generate a TTL square signal of 50% duty cycle. You may want to check the signal on the scope first to make sure it is acceptable.
3. Read the number of pulses as they are arriving. Change the frequency of the input signal and see how that reflects on the speed of counting. Start with a very low frequency (say 1 Hz). What is the maximum frequency you can use with this VI while still getting correct counts? What is the maximum number the counter reaches before wrapping back to 0?
4. Close the previous VI and open the *Measure Low Frequency* VI which is shown in Figure 2. Reconnect the counters as shown in the diagram of Figure 2.
5. Set the Gate Width to 1, and measure the frequency from function generator. Use different gate widths while keeping the frequency fixed. Repeat with a fixed gate width and variable frequencies. Record all your readings in the table provided in the data sheet section. Always note down both the actual and measured frequencies. What range of frequencies can you measure accurately? What are the limitations on the gate width? What happens if the gate width and input signal period are identical? Comment on the results.

## Lab Report

Your report must be typed and of professional quality. You should include the following in your report:

1. All schematics, which must be computer-generated. Components must be labeled with circuit references and values. The schematics must be fully compliant with standard engineering practices for circuit depiction.
2. Front panel and block diagram of all VI's and Sub VI's that you wrote or used.
3. A Theory section describing the theory behind the concepts used in this lab.
4. An implementation section describing the details of your VI code and the logic flow.
5. The tabulated test results and observations.
6. The answers to the Pre-lab questions in the provided datasheet.
7. Selected sections of the datasheet of the PCI 1200.

# Data Sheet

- 1. Answer : .....
- .....
- 2. Answer : .....
- .....
- 3. Answer : .....
- .....
- 4. Answer : .....
- .....

Gate Width (s)	Actual Frequency (Hz)	Measured Frequency (Hz)
0.5		
1		
1		
1		
1		
5		
5		
5		
5		
10		
10		
10		
10		