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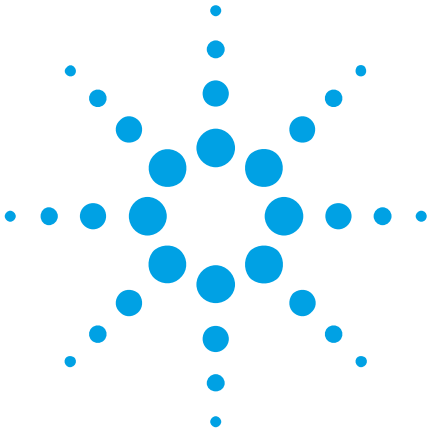
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User Manual

Agilent Acqiris

Time-to-Digital Converters

For Use with TC Series Time-to-Digital Converters

Models covered:

TC840 TC842 U1050A

&

TC890 U1051A

Agilent Technologies

Manual Part Number

U1092-90017

Edition

C-Rev C, July 2012

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1. Out of the Box

1.1. Message to the User

Congratulations on having purchased an Agilent Technologies Acqiris data conversion product. Acqiris Time-to-Digital Converters are high-speed data acquisition modules designed for capturing the exact times of high frequency electronic signals. To get the most out of the products we recommend that you read this manual carefully. We trust the product you have purchased will meet with your expectations and provide you with a high quality solution to your data conversion applications.

1.2. Using this Manual

This guide assumes you are familiar with the operation of a personal computer (PC) running a Windows 2000/XP/Vista/7 (32/64) or other supported operating system. It also assumes you have a basic understanding of the principles of data acquisition.

The manual is divided into 4 separate sections. To understand the elements of operation for the module it is essential that you read them all.

Chapter 1 ***OUT OF THE BOX,*** describes what to do when you first receive your new Acqiris product. Special attention should be paid to sections on safety, packaging and product handling. Before installing your product please ensure that your system configuration matches or exceeds the requirements specified.

Chapter 2 ***INSTALLATION***, covers all elements of installation and performance verification. Before attempting to use your Acqiris product for actual measurements we strongly recommend that you read all sections of this chapter.

Chapter 3 ***PRODUCT DESCRIPTION***, provides a full description of all the functional elements of the Time-to-Digital Converter.

Chapter 4 ***RUNNING THE TC DEMO*** Application, describes the operation of the demonstration program that enables basic operation of Acqiris Time-to-Digital Converters in a Windows 2000/XP/Vista/7 (32/64) environment.

For information necessary for writing your own software to control Acqiris products you should refer to the **Programmer's Guide** and the **Programmer's Reference Manual**.

1.3. Conventions Used in This Manual

The following conventions are used in this manual:



This icon to the left of text warns that an important point must be observed.

WARNING Denotes a warning, which advises you of precautions to take to avoid being electrically shocked.

CAUTION Denotes a caution, which advises you of precautions to take to avoid electrical, mechanical, or operational damages.

NOTE Denotes a note, which alerts you to important information.

Italic text denotes a warning, caution, or note.

Bold Italic text is used to emphasize an important point in the text or a note

`mono` text is used for sections of code, programming examples and operating system commands.

B,KB,MB,GB is for Byte, KiloByte = 1024 bytes, MegaByte = 1024*1024 bytes, GigaByte = 1024*1024*1024 bytes

1.4. Model Names

Agilent Technologies Inc. acquired Acqiris SA and its product lines in December 2006. Use the tables below to cross reference the legacy model name and new Agilent numbers

Agilent Model Number	Acqiris Model Name
U1050A-001	TC840
U1050A-002	TC842
U1051A	TC890

1.5. Disclaimer and Safety

The model TC Series CompactPCI/PXI Timer Counters have been designed to operate inside a CompactPCI/PXI crate. The crate provides the modules with all needed power. Agilent does not recommend operation of the TC Series modules outside of a CompactPCI/PXI crate.



CAUTION: ***Do not exceed the maximum input voltage rating! The maximum input voltage for 50 Ω input impedance is ±5 V.***

1.6. Warning Regarding Medical Use

The Time-to-Digital Converter cards are not designed with components and testing procedures that would ensure a level of reliability suitable for use in treatment and diagnosis of humans. Applications of these cards involving medical or clinical treatment can create a potential for accidental injury caused by product failure, or by errors on the part of the user. These cards are ***not*** intended to be a substitute for any form of established process or equipment used to monitor or safeguard human health and safety in medical treatment.



WARNING: ***The modules discussed in this manual have not been designed for making direct measurements on the human body. Users who connect an Acqiris module to a human body do so at their own risk.***

1.7. Packaging and Handling

Your Time-to-Digital Converter is shipped with the following components:

- A compact disc in an Agilent Technologies paper CD envelope that includes
  - 10 product User Manuals in electronic form (8-bit Digitizers, 10-bit Digitizers, 12-bit Digitizers, Averagers, Analyzers, Signal Analyzers, Streamer Analyzers, Time-to-Digital Converters, 3-, 5-, and 8-slot CompactPCI Crates, and the 21-slot CompactPCI Crate),
  - 1 Programmer's Guide and 1 Programmer's Reference Manual,
  - device drivers with sample software for different operating systems, environments and languages,
  - the Analyzer Demo application, a demonstration program for the AC/SC Analyzer products,
  - the AcqirisLive application, a demonstration program for our digitizer and averager products,
  - the SSR Demo application, a demonstration program for the Acqiris AP235/AP240 Analyzers,
  - the APX01 Demo application, a demonstration program for the Acqiris AP101/AP201 Analyzers,
  - the TC Demo application, a demonstration program for the Acqiris TC840/TC842/TC890 Time-to-Digital Converters,
  - full installation procedures for use with Microsoft Windows, National Instruments LabVIEW RT, Wind River VxWorks, IVI-COM/C, and Linux software.
- A declaration of conformity
- Optional documentation such as a model-dependent document giving Specifications & Characteristics, a Calibration Certificate, or a Performance Verification

After carefully unpacking all items, inspect each to ensure there are no signs of visible damage. Also check that all the components received match those listed on the enclosed packing list. Agilent cannot accept responsibility for missing items unless we are notified promptly of any discrepancies. If any items are found to be missing or are received in a damaged condition please contact the Agilent service center or your local supplier immediately. Retain the box and packing materials for possible inspection and/or reshipment.

1.8. Warranty

All Agilent Acqiris Digitizer products are warranted to operate within specification, assuming normal use, for a period of at least one year from the date of shipment. Units sold before April 2008 had three year warranties, as do some more recent ones; in case of doubt examine your invoice. It is recommended that yearly calibration be made in order to verify product performance. All repairs, replacement and spare parts are warranted for a period of 3 months. Warranty extensions are available as an option.

Agilent endeavors to provide leading edge technology that includes the latest concepts in hardware and software design. As such software and firmware used with the products is under continual refinement and improvement. All software and instrument firmware is supplied "as is" with no warranty of any kind. Software and firmware is

thoroughly tested and thought to be functional at the time of shipment. At Agilent's discretion software and firmware may be revised if a significant operational malfunction is detected.

In exercising this warranty, Agilent will repair or replace any product returned to the Agilent service center, within the warranty period. The warranty covers all defects that are a result of workmanship or materials. This excludes defects that are caused by accident, misuse, neglect, or abnormal operation.

The purchaser is responsible for returning the goods to the nearest Agilent service center. This includes transportation costs and insurance. Agilent will return all warranty repairs with transportation prepaid.

1.9. Warranty and Repair Return Procedure, Assistance and Support

Agilent acquired Acqiris SA and its product lines in December 2006. Please contact your nearest Agilent Service Center before returning any product for repair.

You can find information about technical and professional services, product support, and equipment repair and service on the Web, see http://www.agilent.com/find/service (or http://www.agilent.com/ and after selecting your country click on **Contact Us**). The service center will ask for your name, company, phone number and address, the model and serial numbers of the unit to be repaired, and a brief description of the problem.

Before issuing a Service Order the service center may ask you to communicate with us by phone or eMail so that we can learn as much as needed about the problems observed. If a unit returned under guarantee is found to be working normally and this procedure was not followed we reserve the right to charge you for the work done.

For your nearest customer support center please contact Acqiris Technical Support (ACQIRIS_SUPPORT@agilent.com) or come visit our web site at http://www.agilent.com/find/acqiris. Alternatively, contact Acqiris at 1-(800)829-4444 in the USA, +41 22 884 32 90 in Europe or +61 3 9210 2890 in the Asia-Pacific region. The Agilent Support Centers can also help redirect you for any questions concerning the installation and operation of your equipment.

1.10. System Requirements

Acqiris products need the following minimum PC System Requirements in order to obtain reasonable performance from your digitizer.

Processor: 500 MHz Pentium (higher recommended). Some PowerPC systems running Wind River VxWorks are supported; please contact us for details.

Memory: 256 MB RAM. The previous number is a very rough estimate. Assuming that you are using AcqirisLive or an application of your own that operates on the acquired data it seems reasonable to ask for 10 times the total acquisition memory that you will be using at the same time in the application. Performance is likely to be degraded if less memory is available.

Display resolution: At least 1024 x 768 pixels and 256 colors for use of AcqirisLive or Demo applications.

Operating System: Microsoft Windows Vista, Vista 64-bit, 7, 7 64-bit, 2000/XP including 2003 Server, Wind River VxWorks 5.5.1 and 6.4, and Linux with kernels 2.4 and 2.6. Users with previous Windows OS versions (i.e. NT4) can download AcqirisSoftware 3.1 from the Agilent WEB site.

⚠ ***NOTE:*** *Windows 2000 will not be supported in future releases.*

⚠ ***NOTE:*** *Wind River VxWorks 5.5.1 will not be supported in future releases.*

Hard Drive Space: 300 MB for the Complete installation.

CD Drive (or any method to copy the software installation files from CD to the hard drive such as LAN, floppy drive, etc.)

LabVIEW: Full driver implementations are available for National Instruments LabVIEW versions 8.5, 8.2.1, and 8.0. LabVIEW 7.1 is frozen at the level of Acqiris Software 3.2 with support for all instruments.

LabVIEW RT: National Instruments LabVIEW RT is supported for the same versions as shown above. The VISA driver must be version 3.0 or higher.

MATLAB: The MEX interface can be used with MathWorks MATLAB 7.3 or a newer version.

Visual BASIC: The interface files and examples are available for Microsoft Visual Basic .NET.

Tornado: The example files are useable with Wind River Tornado 2.2.1.

1.11. Transport & Shipping

CAUTION: ***Cards can be safely transported in their original shipping packages. TC cards can be transported when properly mounted in a CompactPCI crate.***

To package the instrument for shipping:

Step	Notes
1. Place the instrument in its original packaging materials.	• If the original packaging materials are not available, use a professional packaging service. Contact your Agilent Service Center for more information.
2. Surround the instrument with at least 3 to 4 inches (8 to 10 cm) of its original packing material or bubble-pack to prevent the instrument from moving in its shipping container.	
3. After wrapping it with packing material, place the instrument in its original shipping container or a strong shipping container that is made of double-walled corrugated cardboard with 159 kg (350 lb) bursting strength.	• The shipping container must be large and strong enough to accommodate your instrument and allow at least 3 to 4 inches (8 to 10 cm) on all sides for packing material.
4. Seal the shipping container securely with strong nylon adhesive tape.	
5. Mark the shipping container "FRAGILE, HANDLE WITH CARE" to help ensure careful handling.	
6. Use the address obtained from your Agilent Service Center.	
7. Retain copies of all shipping papers.	

CAUTION: ***Damage can result if the original packaging materials are not used. Packaging materials should be anti-static and cushion the instrument on all sides. NEVER USE STYRENE PELLETS IN ANY SHAPE AS PACKAGING MATERIALS. They do not adequately cushion the instrument or prevent it from moving in the shipping container. Styrene pellets can also cause equipment damage by generating static electricity or by lodging in fan motors.***

1.12. Maintenance

The cards do not require any maintenance. There are no user serviceable parts inside. A periodic calibration can be obtained on request.

1.13. Cleaning

Cleaning procedures consist only of exterior cleaning.

Clean the exterior surfaces of the module with a dry lint-free cloth or a soft-bristle brush. If any dirt remains, wipe with a cloth moistened in a mild soap solution. Remove any soap residue by wiping with a cloth moistened with clear water. Do not use abrasive compounds on any parts.

1.14. Disposal and Recycling



Electronic equipment should be properly disposed of. Acqiris Instruments and their accessories must not be thrown out as normal waste. Separate collection is appropriate and may be required by law.

2. Installation

This chapter describes how to install the Acqiris hardware and software for Windows, National Instruments LabVIEW RT, Linux, or Wind River VxWorks.

⚠ ***NOTE:*** *For a first time installation we strongly recommend installing the software* ***before*** *inserting the hardware into the PC.*

2.1. U1091AK02 IC414 Installation

⚠ ***NOTE:*** *If you are going to install an IC414 interface for the first time and are running Windows 2000/XP you should follow the procedure below* ***before*** *installing the Acqiris hardware.*

2.1.1. IC414 Hardware installation hints

The PCI-8570/PXI-8570 User's Manual (Rev. 1.00) section 2.5 gives Hardware Installation instructions.

⚠ ***CAUTION***: ***Turn off the power of the PC; the PC may have to be unplugged to ensure that the PCI bus has no power available.*** Please ignore the PCI-8570 instruction to leave the power cord plugged in; Ground the chassis differently!

⚠ ***CAUTION:*** ***Touch the antistatic package to a grounded object before removing the card from the package. Electrostatic discharge can damage the card.***

The standard cable pair provided each have a red connector on one end and a black connector on the other. Therefore the correct connection can be made by plugging the Red connector into the L0Rx socket and the Black connector into the L0Tx socket on the PXI module and the other Red connector into the PCI module socket furthest from the PCI card internal base connector and the Black connector into the next socket.

If you intend to use 64-bit 66 MHz transfer to maximize data transfer speed you should cable a “bundled link” using two standard cable pairs and both the L0 and L1 pairs of connectors. You should also make sure that you configure the PXI-8570 M66EN Jumper correctly.

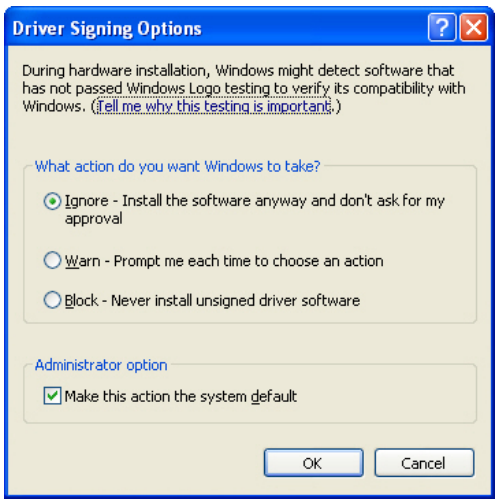
2.1.2. IC414 Windows software installation

Windows Vista/7 (32/64), XP64 and Linux users do not need to read any further since there is no special software installation.

Windows users should have the hardware installed as noted above. This software installation should be done before any Acqiris modules are placed in the CompactPCI crates. This may mean that you have to remove the module from the crate *as delivered*.

The crate should be turned on first followed by the PC. If the cabling and start-up sequence is done correctly there will be no LED illuminated on the PCI unit connected pair and the LED's of the PXI connected pair will be lit.

For **Windows XP** installation, Select the **Control Panel** under Settings in the **Start** menu. Then, if you are using the **Category View** select **Printers and Other Hardware.** After this, for both **Category** and **Classic** views, go to **System** and then display the **Hardware** tab to get access to the **Driver Signing** menu. Since neither the AdLink nor the Acqiris driver has been submitted for **Windows Logo testing** you must select either the **Ignore** or **Warn** action. The resulting menu looks as shown:



The PCI-8570/PXI-8570 User's Manual (Rev. 1.00) section 2.4 contains the software installation instructions. These should be executed before allowing the hardware installation process to look for the driver. If you have an AdLink CD Version 2004A4 or later you can use it; if not you should download the latest driver from the WEB site (http://www.adlinktech.com/). You can then continue with the Hardware Installation. A reboot will then be necessary. At this point the Stargen Fabric PCI Adapter and the Stargen Aruba Fabric-to-PCI Bridge should appear correctly installed under System Devices in the Device Manager.



NOTE: If you have an AdLink CD Version 2005A3 or later you can find 8570install.exe in the folder X:\Driver Installation\PXI Platform\PXI Extension\PCI_PXI-8570\Wnt2kxp and the starfab1.inf file in the folder X:\Driver Installation\PXI Platform\PXI Extension\PCI_PXI-8570\Win98.

2.2. Installing the Software under Windows

2.2.1. Warnings

If Setup detects a previous installation of Acqiris software on your system, a warning screen will be displayed. It is recommended to exit Setup and uninstall older versions.

The installer from software releases prior to **Acqiris Software 2.0** installed the Digitizer Driver DLL files into the System directory. These will be removed by Setup. If you wish to keep the old installation on your system, you should exit Setup, and move all Acqiris driver files (acqiris*, acqrs* and acqir*) to some archive directory.

The DLL files will be installed into the bin subdirectory of the Acqiris software root, and the corresponding path will be added to the PATH environment variable.

2.2.2. Multiple Versions

With the software installation from **Acqiris Software 2.0** or above, it is possible to keep multiple versions on the same system, but you must specify a different root directory (i.e. Install Folder). If you keep the same directory, Setup will overwrite your previous installation.

To go back to a previous version, you must change the PATH environment variable and reinstall the Kernel driver.

1. Copy the SYS file from `<old_AcqirisSoftware_root>\bin\kernel` to the `Windows\System32\drivers` directory.
2. Change the AcqirisDxRoot, AcqirisDxDir and PATH environment variables to the old root.
3. Reboot the computer.

2.2.3. Installation

For a first time installation on your computer Agilent recommends that you install the software BEFORE installing the hardware on your system. When upgrading to a new version, you should leave your modules installed and powered during installation.



NOTE: **You will need administrator privileges to complete the software installation under Windows.**

Complete the following steps to install the software for Windows 2000/XP/Vista/7 (32/64).

1. Insert the *Acqiris Software CD* into the CD-ROM drive of your computer. If the Autorun program does not start automatically (Autoplay disabled), you can start it manually, or navigate to the *AcqirisSoftware\Windows* folder in order to display the files included.
2. Choose **Install AcqirisSoftware for Windows 2000/XP/2003 Server/Vista/7** (or run `Setup.exe` from the *AcqirisSoftware\Windows* folder). After several seconds for initialization the first of many screens will appear.

Please note the following points:

- It is good practice to remove any previously installed version of Acqiris software. If the program finds that there is still Acqiris software installed on your machine a warning panel will appear.
- When upgrading from an old version under Windows 2000, you must uninstall all Agilent Acqiris devices manually prior to running the installer.
- In the **Select Install Type** window selecting **Custom** installation will let you select individual packages for loading. The space indicated for LabVIEW, Firmware and UserManual packages is incorrect. The correct values are 7 MB, 40 MB, and 30 MB respectively. A full installation requires just under 300 MB of disk.

- If MATLAB is installed on your machine, you will be asked to point the installer to the MATLAB root directory. You should do this if you want the installer to modify the standard startup.m file to add the paths for the MEX interface.
- In the **Installation Folder** window you will give the name of the root directory of the Acqiris software installation. If User Manuals (30 MB) and Firmware (40 MB) are loaded more space than indicated here will be required on the drive. For the case of a Tornado 2.2 installation the folder name should not contain any spaces.
- AcqirisLive needs the LabWindows/CVI 8.0 Run-Time Engine to run. If Setup has detected that a LabWindows/CVI Run-Time Engine is already installed on your system, it will ask you if you would like to install it locally for AcqirisLive anyway. If you are not sure about the version of the CVI Run-Time Engine on your system, it is recommended to install it locally.
- The **Installation Summary** window will be shown to allow you to check what you have asked for. At this point it is not too late to go back and make changes. The actual installation will only be started after clicking on "Install" in the next window.
- Please read the **IMPORTANT Information** window text. It could help you avoid serious problems.
- Registration of your installation will help Agilent provide you with better support. You will also be notified of updates and upgrades. All information submitted will be treated in accordance with Agilent's privacy policy. Setup will prepare a registration e-mail in your e-mail client application upon termination of the setup procedure. You can then decide whether or not you wish to send it. You may also add comments. Uncheck the box if you do not want to register your installation.
- After the software installation is complete you can either accept the suggestion to restart the computer or you should shutdown your computer and proceed with the hardware installation.

2.3. Installing the Software for Linux

Please refer to the README file on the Acqiris Software CD-ROM (AcqirisSoftware/linux folder) for detailed instructions to install the software for linux systems.

2.4. Installing the Hardware

1. Turn off the power of the PC and the crate in the case of a CompactPCI module.

⚠ ***CAUTION:*** ***For PCI modules the PC may have to be unplugged to ensure that the PCI bus has no power available. However, CompactPCI crates can be left plugged in since this ensures proper grounding.***

⚠ ***CAUTION:*** ***Touch the antistatic package to a grounded object before removing the card from the package. Electrostatic discharge can damage the card.***

2. Module in a PC: open the PC, identify a free PCI slot and carefully insert the DP Series card into it. Be sure to ground yourself by touching the grounded PC frame and avoid touching any components on the DP Series card. Make sure that the grounding of the card's mounting bracket to the back panel rail of the computer is done correctly. If present make sure that the fan's adjustable retainer is correctly positioned and tightened for mechanical support. Close the PC.

   Module in a CompactPCI crate: Follow the instructions of the crate manufacturer to insert the DC Series card into a free CompactPCI peripheral slot. Be sure to ground yourself by touching the grounded crate and avoid touching any components on the DC Series card. Be sure to tighten both front panel mounting screws to lock the module into place and insure proper grounding of the frame.

⚠ ***NOTE:*** *To ensure the best possible performance, users of Acqiris CC121 Crates with AS bus systems should respect the module placement rules to be found in the Agilent Acqiris 21-slot CompactPCI Crate User Manual.*

   PCI Bus extension module in a PC: Consult the manufacturer's documentation for any special instructions. Open the PC, identify a free PCI slot and carefully insert the card into it. Be sure to ground yourself by touching the grounded PC frame and avoid touching any components on the card. Make sure that the grounding of the card's mounting bracket to the back panel rail of the computer is done correctly. Close the PC. Connect the module to the CompactPCI crate controller.

3. Turn on the power of the crate(s), if present, and then the PC and start the operating system.

⚠ ***NOTE:*** *Acqiris digitizers are equipped with a LED. If this LED is not glowing orange or red when the power is applied there is a severe problem. Either the module is broken or the necessary voltages for its use are not available.*

⚠ ***NOTE:*** *For proper system operation when using the IC200, IC414, or other PCI extension interface to connect a CC10X crate to a remote PC, the crate* ***must*** *be powered on before the PC in order for the PC BIOS to recognize the presence of the CompactPCI crate.*

4. If devices were installed using a previous version of Acqiris software the instruments in these logical positions may still appear as *Unknown Devices*. This can be changed to the new Acqiris type category with the Grey Diamond icon by **Uninstall**ing the device and then **Installing** again. Instructions on this procedure can be found in the **ReadMe.txt** file in the **manuals** folder of your Acqiris software installation.

2.5. After Restarting

2.5.1. Windows 2000

Under Windows 2000, you *must* login with administrator privileges after the first boot following the hardware installation; the Plug&Play system must have the appropriate privileges to be able to complete your hardware installation successfully. After a successful hardware installation, you will be able to use your Acqiris digitizer(s) with normal privileges.

At the first boot following the hardware installation, Windows will detect the new hardware and will install the devices automatically. The following image will appear.



⚠ ***NOTE:*** *In some systems an application program (such as AcqirisLive) will not yet work correctly at this point. One additional boot cycle may be needed if this is the first time that a hardware board is being installed.*

2.5.2. Windows XP/Vista/7

Under these Windows versions, you *must* login with administrator privileges after the first boot following the hardware installation; the Plug&Play system must have the appropriate privileges to be able to complete your hardware installation successfully. After a successful hardware installation, you will be able to use your Acqiris digitizer(s) with normal privileges.

If you login with administrator privileges after the first boot following the hardware installation, Windows will detect the new hardware and start the “Found New Hardware Wizard” after a few seconds. There is no need to use Windows Update to search for the software. You can “Install the software automatically”. The final screen should appear as shown here:



⚠ ***NOTE:*** *In some systems an application program (such as AcqirisLive) will not yet work correctly at this point. One additional boot cycle may be needed if this is the first time that a hardware board is being installed.*

2.6. LabVIEW RT

During program development you can choose whether you use LabVIEW or LabVIEW RT compatible libraries by switching the version present in **National Instruments\LabVIEW m.n\instr.lib**. This swap can be facilitated by using the **Install VI library for LabVIEW or LabVIEW Real-Time** shortcut available in the Shortcut folder under **Start** → Programs.

There is only one Acqiris Driver. It supports all Acqiris Instruments. The instructions below concern LabVIEW RT as used in NI PXI processors.

The Aq_RT.inf and AqRT_4.ini files must be uploaded to the target. To do this,

- start the MAX application,
- right click on the target
- select file transfer
- select the Aq_RT.inf file on your host machine and upload ('To Remote') to the LabVIEW RT working directory (/NI-RT/system) on the target
- select the Aq_RT.ini file on your host machine and upload ('To Remote') to the LabVIEW RT working directory (/NI-RT/system) giving it the name AqDrv4.ini

For Acqiris modules which need FPGA files you should,

- create the folder \firmware in the /NI-RT/system directory using the file transfer application
- select the FPGA files (from <AcqirisDxRoot>\Firmware) you want to copy to the target and upload them into the firmware directory

Restart the target after finishing the file transfers.

Restart the MAX Explorer and you should have Acqiris digitizers detected in your PXI system.

2.7. Installing the IVI-COM/C Driver

Please install Acqiris software for Windows first. Then the *Acqiris Software CD* Autorun program gives access to two installers:

- IVI Shared Components 1.4
- IVI-COM/C IviAqD1 driver

These must be installed in the order shown above. For more information you can then consult the Readme.txt file in the IVI\Drivers\IviAqD1 folder or the documentation through the program shortcut present under Ivi/IviAqD1.

2.8. Uninstalling devices under Windows

In the Device Manager, select the instrument to be uninstalled. Choose “Uninstall” from the “Action” menu. After all desired instruments have been uninstalled select “Scan for hardware changes” from the “Action” menu, or reboot the computer. Note that only those devices that are actually physically present are visible in the Device Manager.

2.9. Distribution for Windows 2000/XP/Vista/7 (32/64) and Linux

The manuals/ReadMe.txt file contains a list of files to be found after a complete installation of Acqiris software on Windows systems. Similarly the ReadMeLinux file gives the list of files corresponding to that installation.

3. Product Description

3.1. Overview

Time-to-Digital Converters are instruments to do high resolution measurement of time intervals between hits on any one of many channels and a common channel. A hit is defined as a simple threshold occurrence where the input signal passes through the desired threshold in the desired direction. An event is a collection of channel hits associated with a single common start. These instruments can be viewed as free running high resolution (5 ps or 50 ps) counters with each individual channel capable of recording the time of arrival of edge signals and storing this data in the local memory. They differ in the number of input channels, their Double Pulse Resolution, and their multihit capability.

The TC family contains the models with characteristics as shown in the table below.

Model Agilent #	**Channels**	**Resolution**	**Range**	**Comments**
TC840 U1050A-001	12 + Common start	50 ps	21.47 s	Ramp, Single hit
TC842 U1050A-002	12 + Common start	5 ps	21.47 s	Damped sine wave, Single hit
TC890 U1051A	6 + Common start	50 ps	10.48 ms	TOF, Ramp, Multihit

The TC840/TC890 units employ a counter together with a TDC using a ramp triggered by the incoming signal to achieve the desired resolution. The TC890 with its multihit capability is targeted at Time-of-Flight (TOF) applications.

The TC842 units employ the same counter together with a TDC using a damped sine wave triggered by the incoming signal to achieve its impressive resolution.

3.2. Channel Input

- Connectors: 50 Ω K-Lock (LEMO) type (Fischer DLP101 A004-14)
- Impedance: 50 Ω ± 1%, VSWR < 1.5:1 DC to 1 GHz
- Threshold: programmable level –1.5 V to +1.5 V, in 0.7 mV steps
- Slope: programmable + or –. The TC890 can also be used in a pulse mode to measure the time of the two edges of a pulse
- Protection: protection diodes clamping at ± 2.0 V, 0.5 W max into 50 Ω
- Sensitivity: 100 mV over threshold for 350 ps, minimum pulse to fire
- Hysteresis: 15 mV
- Propagation Delay Skew: Δt_{pd}=15 ps 10 mV to 100 mV;
  Δt_{pd}=40 ps 100 mV to 2 V

3.3. Time base

- Internal Clock source: low phase noise PLL,
  jitter < 2 ps RMS, measured over 10ms
- 10 MHz internal reference: < 2 ppm accuracy and stability, 0 to 45°C
- Integral Nonlinearity: ±50 ps
- Differential Nonlinearity: ±30 ps
- Post-start Dead Time: <15 ns. Stops too close to a start may be lost.
- Pre-start Dead Time: <15 ns. Stops too close to a start may be lost.

- External Clock Reference: User defined 10 MHz Reference
  [0, 3 V] range into 50 Ω (diode clip)
  Threshold at 1.5 V

3.4. Other signals

The unit also provides two programmable front panel Auxiliary I/O connectors that can generate or react to GTLP signals. The GTLP signal levels have a nominal 1.5 V HIGH level and a switching reference level of 1.0 V. Additional *input* control signals available include

- Veto - a common veto level that disables hit acquisition* while it is HIGH. The HIGH state is defined by a Threshold in the same way as described for the Channel Input above. At driver initialization the threshold is set to 1.5 V to avoid an unintentional HIGH state. (*Note: On TC890 (U1051A) whilst the veto disables hit acquisition on the channel 1-6 inputs, it does not disable the Common Start (COM IN) input)
- Invert Veto - a common veto level that disables hit acquisition while it is LOW. The LOW state is defined by a Threshold in the same way as described for the Channel Input above.
- Switch Veto - a common veto level that disables the TC890 bank switch mechanism while it is HIGH. The HIGH state is defined by the Veto threshold in the same way as described for the Channel Input above.
- Invert Switch Veto - a common veto level that disables the TC890 bank switch mechanism while it is LOW. The LOW state is defined by the Veto threshold in the same way as described for the Channel Input above.
- Arm - a pulse that can be used to prepare the counter to accept a Common Start. It should be given at least 150 ns before the arrival of any Common Start. (TC840/TC842 only)
- Stop - a pulse that can be used to end an ongoing acquisition (TC840/TC842 only).
- Bank Switch - this will force a bank switch while it is HIGH (TC890 only).
- Marker - a pulse that forces the entry of a marker record into the memory while it is HIGH (TC890 only).

Additional *output* control signals available include

- READY – a TC840/TC842 capability to show that the module can accept the first Common Start of an acquisition.
- GTLP low level - a TC890 ONLY capability to output a DC level.
- GTLP high level - a TC890 ONLY capability to output a DC level.
- Repetitive pulse generator – a TC890 ONLY capability to generate GTLP logic pulses with programmable low-level and high-level widths, both in the range [10, 2550] ns with steps of 10 ns

3.5. Time-to-Digital Converter Operational States

The system can be in any one of the following states:

LED	State	Description
RED	INIT	the state before the first ARM command
GREEN	READY	the state after an ARM and before the first START of an acquisition. The TC840 and TC842 can be configured to give an output HIGH level when the counter is in this state.
ORANGE	ACCEPT	the state after the first START of an acquisition
RED	END_ACQ	the state after the acquisition has ended. At this point the data can be read and a new acquisition started.

An acquisition can be ended in many different ways:

- Hardware timeout occurs. This timeout is programmable through the API and can be set to a time < ~16.1 s. If set to 0 then no timeout will occur. It is implemented with the 33 MHz cPCI clock. This means that it will not have an exact value.
- Hardware maximum time value occurs (~16.1 s)
- All stops received for the last segment of an acquisition - TC840/TC842
- Software stop received

If the Front Panel LED is not lit when the software is started then the counter is not operational. Several software and hardware aspects should be checked; common problems include module recognition and loading of the FPGA bit file.

3.6. TC840 Operation

The TC840 basically takes a common start as a trigger and measures the time interval to the first stop on each of the 12 channels. The device can be either configured for a simple acquisition with readout after every start-stop group or as an acquisition with 512 segments each containing a start-stop group. The maximum time for the stop-start difference is 21.47 s. The entire acquisition will be stopped if the maximum time is reached for a start.

The timing information of the start and stop hits on all 13 channel inputs is obtained by combining a coarse-grain (5 ns) wide-range (32 bits) real-time count with a much finer grained interpolated result coming from the analysis of a ramp signal started by the hit. Each channel consists of a programmable comparator, an XOR gate used to select the active slope, a stable signal generator, and an analog to digital converter (ADC). Once digitized, the data are fed to a Xilinx Virtex-2 Pro FPGA-based Data Processing Unit (DPU) for storage and readout.

Each channel is processed to determine the real time of each detected hit, start and stop. The final relative time value is obtained by subtracting the start time from each stop time. The large internal memory buffer on the card allows the recording of up to 512 events per channel.

In the simple acquisition mode a readout of 104 bytes must be done to access the data. In the multiple acquisition mode this read will contain 52KB. If the fast direct memory access (DMA) readout mode is used the data can be transferred at up to 100 MB/s.

3.7. TC842 Operation

The TC842 basically takes a common start as a trigger and measures the time interval to the first stop on each of the 12 channels. The device can be either configured for a simple acquisition with readout after every start-stop group or as an acquisition with 128 segments each containing a start-stop group. The maximum time for the stop-start difference is 21.47 s. The entire acquisition will be stopped if the maximum time is reached for a start.

The timing information of the start and stop hits on all 13 channel inputs is obtained by combining a coarse-grain (5 ns) wide-range (32 bits) real-time count with a much finer grained interpolated result coming from the analysis of a damped sine wave signal started by the hit. Each channel consists of a programmable comparator, an XOR gate used to select the active slope, a stable signal generator, and an analog to digital converter (ADC). Once digitized, the data are fed to a Xilinx Virtex-2 Pro FPGA-based Data Processing Unit (DPU) for storage and readout.

Each channel is processed to determine the real time of each detected hit, start and stop. The final relative time value is obtained by subtracting the start time from each stop time. The large internal memory buffer on the card allows the recording of up to 128 events per channel.

In the simple acquisition mode a readout of 416 bytes must be done to access the data. In the multiple acquisition mode this read will contain 52KB. If the fast direct memory access (DMA) readout mode is used the data can be transferred at up to 100 MB/s.

3.8. TC890 Operation

The TC890 basically takes a common start as a trigger and measures the time interval to stops on each of the 6 channels. There are two time to digital conversion circuits per channel. When one has acquired a hit the second is enabled and vice-versa. The enable control logic allows the system to achieve a continuous Double Pulse Resolution (DPR) of ~15 ns for normal hits or ~15 ns minimum pulse width in that mode. The timing information of the start and stop hits on all 13 circuits is obtained by combining a coarse-grain (5 ns) wide-range (22 bits) real-time count with a much finer grained interpolated result coming from the analysis of a ramp signal started by the hit.

The TC890 has a ping-pong memory architecture, enabling data readout while the module still continues to acquire events. The switch from one memory bank to the other can be done under three different circumstances:

- Bank Full - where Full is a programmable value of at least 192 bytes. Start, stop, and marker records all need 4 bytes each. The switch is not exact but will guarantee that the programmed size is not exceeded.
- Event Count - where Event Count is a count of hits on the Common channel.
- Triggered by an external signal - where the signal is selectable from either one of the Auxiliary inputs (I/O Aux1 or I/O Aux 2).

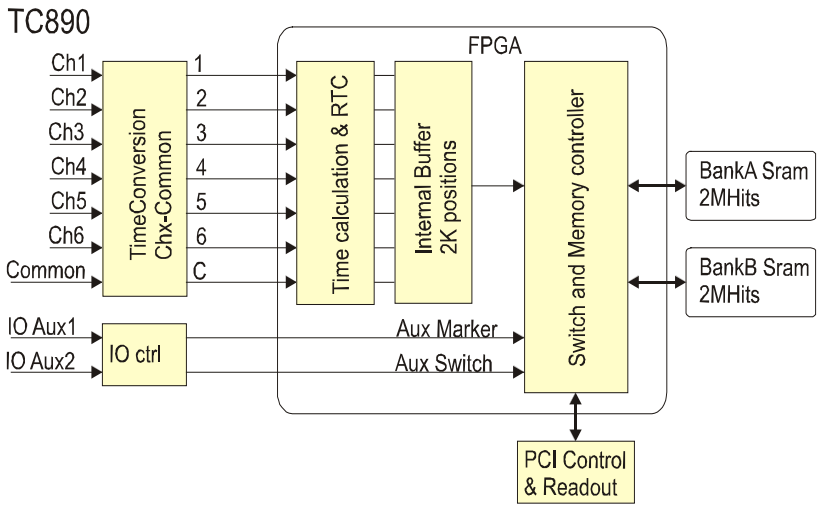
However the bank switch can only occur if the next bank is free. A bank containing data is only freed after a read out operation has been performed. Memory switch conditions should be adjusted so that the pernicious buffer full condition is avoided as much as possible. The counter can both convert more hits than it can continuously stream to the PCI and acquire hits faster than writing them to the external memory. Therefore, it is important to configure the module in order to avoid losing important data. An Event Count switch will occur after the desired number of events has been acquired and the next common start occurs.

Hardware signal derived data markers can be introduced into the data stream so that they can be readout with the flow of events. Rising edges on either of the Auxiliary inputs can trigger the write of a marker to memory.

The nominal range limitation of 10.48 ms can be completely removed if a channel can be dedicated to the measurement of a known repetitive pulse. A square wave with a period just under 200 Hz would be appropriate.

3.8.1. Data flow Block Diagram

The purpose of the external memory is to acquire a large number of records which will be readout in DMA mode, to reduce the readout time. Each record consists of 4 bytes and is either a marker or a time value from a hit in a particular channel, or the start. Data can be read out at a rate of 25 Mrecords/s. The DMA configuration introduces an overhead of ~150 us, which depends strongly on the activity on the computer and, of course, on the operating system.



3.8.2. Internal Buffer

The internal buffer can store the records at the maximum continuous rate given above on all channels and on the common input. The total is then 7 x 50Mrecords/s = 350Mrecords/s.

⚠ ***NOTE:*** **In real applications this is normally not the case. But as the readout of the internal buffer is actually limited to 50Mrecords/s you should be aware that if the hit rate at the input becomes too high for too long a time, the internal buffer will fill up and new incoming hits will not be stored. They will be lost, with the exception of the last hit on the common input which is always memorized in order to always keep the latest time reference. If the internal buffer becomes full, the status InternalBufferFull becomes true. It is a good idea to verify if it was the case or not.**

The hits on the Common channel are also written to the memory and are part of the readout data

3.8.3. DMA overhead

When a bank is ready to be read, an interrupt is generated and the readout will start after some time. On average with Windows 2000, the delay is ~150 us. The readout itself runs at ~100 MB/s which is equivalent to ~ 30Mrecords /s. In order to achieve an overall average rate of ~25Mrecordss/s, you should ensure that the minimum size of the buffer to be transferred is ~27K records.

3.9. Internal Calibration

For accurate time measurements it is recommended to perform a calibration once the module has attained a stable operating temperature (usually reached with a few minutes after power on). Further calibration should not be necessary unless temperature variations occur. Recalibration is to be recommended if the measured temperature has changed by 5°C or more. This self calibration is done simply through a software command available in the driver, so no extra programming is needed. It adjusts the slope and offset of the ramp signal for optimal performance.

3.10. Electrical, Environmental and Physical Specifications

3.10.1. Electrical

Max. Power (W)	**Current Requirements (A)**			
	+12 V	**+5 V**	**+3.3 V**	**−12 V**
27 W	0.09	4.13	0.73	0.05

The Maximum Power Consumption has been increased by 10% over the value calculated with the currents shown to take into account higher allowed values of the crate voltages.

All Acqiris Time-to-Digital Converters conform to Revision 2.2 of the PCI Local Bus Specification and use the PCI Bus at 33 MHz. All of these modules are capable of DMA transfers at rates ~100 MB/s.

3.10.2. Environmental and Physical

The modules have a Declaration of Conformity according to ISO/IEC Guide 22 and EN45014 and **CE** Marks of Compliance.

The front panels of the CompactPCI modules are in compliance with the IEEE 1101.10 standard.

Operating Temperature

0° to 45°C

The above values are for the ambient temperature of the room (or equivalent) where the CompactPCI crate is located. The temperature as measured at the board may well be significantly higher. On-board temperatures above 60°C should be avoided.

Relative Humidity

5 to 95% (non-condensing)

Dimensions

The TC modules conform to the 6U CompactPCI standard (233 mm × 160 mm × 20 mm).

EMC Immunity & Emissions

Complies with European EMC Directive 2004/108/EC
• IEC/EN 61326-2-1
• CISPR Pub 11 Group 1, class A
• AS/NZS CISPR 11
• ICES/NMB-001

This ISM device complies with Canadian ICES-001.
Cet appareil ISM est conforme à la norme NMB-001 du Canada.

Required Airflow

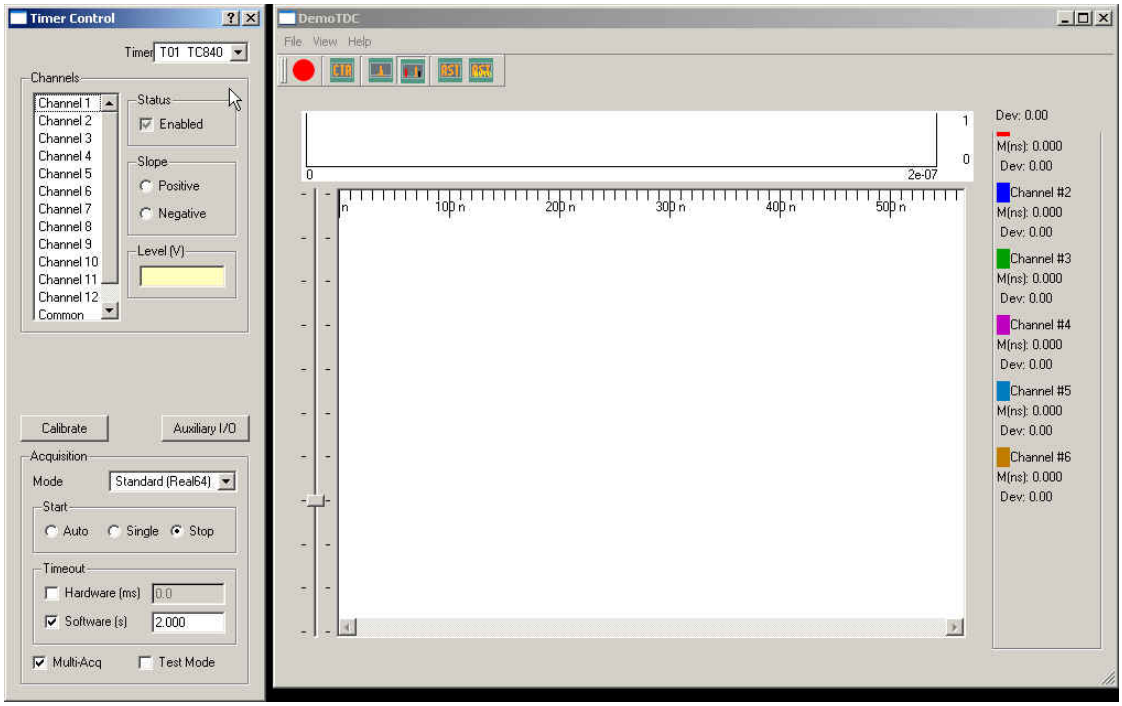
> 2 m/s in situ

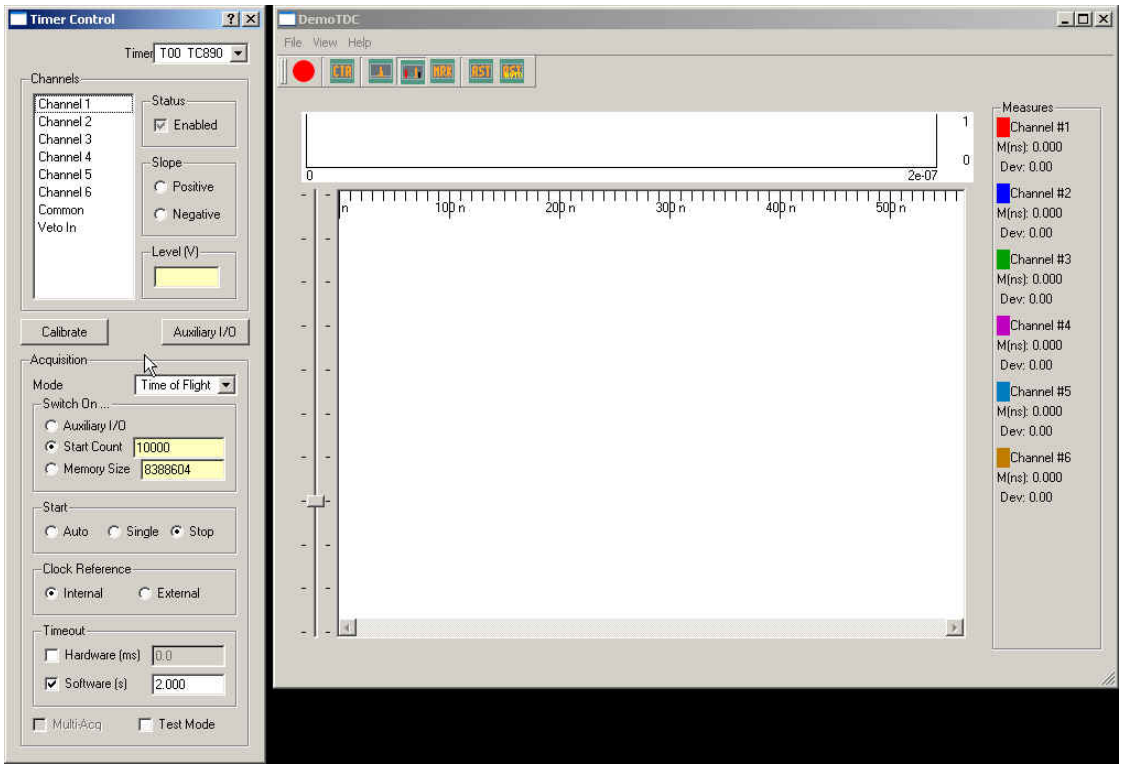
4. Running the TC Demo Application

The TC Demo program is provided as a simple visualization tool to help understand the spectra of measured times of arrival of signals on each of the 6 or 12 input channels (INPUT-n) with respect to the common REF IN.

Once the standard Acqiris Hardware and Software Installation is complete you will be able to start the program by activating it either from the shortcut in the Start menu, from the Windows Explorer, or by creating another shortcut to it. It is DemoTC.exe in the AcqirisApp directory of the Acqiris software installation. After a few seconds of initial calibration the program will open two windows.

This application shows two panels. The left panel has all of the controls needed to set the parameters of the board. The right panel displays the data read from the TC840, TC842, or TC890 in various formats. Here we show the initial appearance of the application for these two cases:





4.1. The Timer Control panel

The top Timer box allows the selection of the instrument to operate on. Whenever there is more than one TC instrument in the system, the identification of the current one is displayed.

The 'Channels' area gives the ability to control the settings of each channel. Whenever a group of channels is selected from the list on the left, it is possible to control them together. A group of channels can be selected by using the Ctrl key together with the mouse to select each channel desired. Dragging to select consecutive ranges is allowed. The following settings can be changed:

- Status to turn on/off the channels in the group
- Slope to set the desired slope of the timing edge
- Level to set the desired voltage for the transition to be measured. This voltage must be in the range [−1.5,+1.5 V] and can be adjusted with a granularity of 1 mV.

The Calibrate button can be used to force a calibration of the instrument. Note that a calibration is made automatically when the program is started.

The 'Acquisition' area gives control of the operating mode of the instrument and related parameters. These settings are explained in the next sections.

4.1.1. The Acquisition area

The 'Mode' box selects the operating mode of the instrument. For the TC840 or TC842, the event readout can be done either in Standard (Real64) mode for times in ns, or, for the TC840 only, in (Int32) mode for integer times that are multiples of the 50 ps. granularity. For the TC890, it contains only one choice, the 'standard' acquisition mode of the counter concerned.

In the 'Start' area, the three radio buttons are used to control the timer:

- The 'Stop' button can be clicked to stop a running instrument.
- The 'Single' button starts a single acquisition and once it is done the Start display returns to the stopped state.
- The 'Auto' radio button runs acquisitions repeatedly until another button is selected.

The 'Timeout' value is a software or hardware timeout that makes the instrument stop the current acquisition if it is not finished after the specified time. It is given in the unit shown and this can have a fractional part.

The TC840/TC842 'Multi-Acq' check box allows the instrument to run in a multiple acquisition mode instead of the single acquisition mode. This is explained below.

The 'Test Mode' button enables an internal test signal that triggers each channel at a rate ~1 MHz.

4.1.2. Other controls

Additional controls include a button to select a menu to control the I/OAuxiliary connector signals. This contains a radio button pair to select the internal or external reference clock. Note: This is available for all models.

4.1.3. TC840/TC842 Multiple acquisition

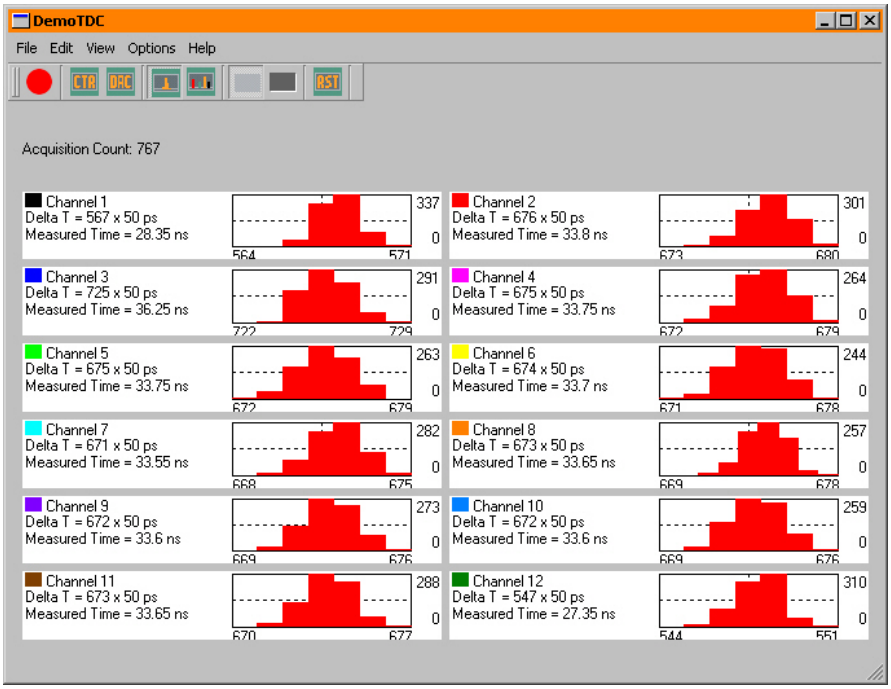
When 'Multi-Acquisition' is left unchecked, the instrument performs one acquisition at a time. It waits for a hit on the common channel, and then for a hit on each of the other enabled channels. When all have been hit, it declares the acquisition finished.

Whenever 'Multi-Acquisition' is selected, the instrument behaves differently. It first waits for a hit on the common channel, and then waits for a hit on each of the other enabled channels. But if another hit comes on the common channel, it goes to the next acquisition, and waits again for hits on the other enabled channels. It repeatedly advances to the next acquisition, until it has no space left in memory. It currently has a capacity of 512 acquisitions for a TC840 or 128 in the case of the TC842. For each acquisition, the channels that had no hits are marked with a special value.

4.2. TC Demo Window

4.2.1. Histogram Display

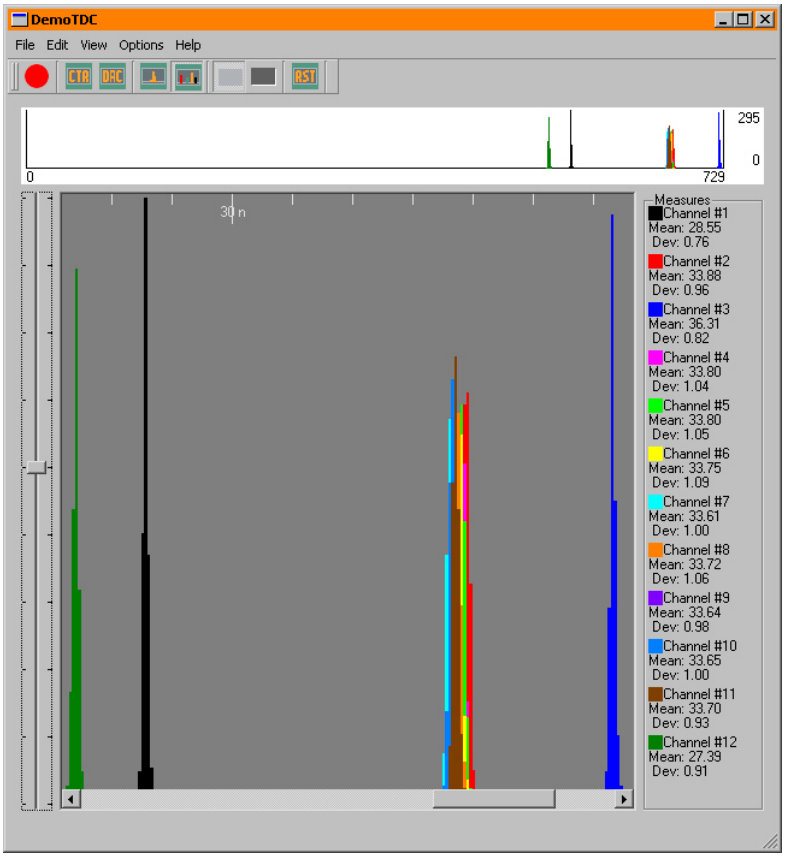
The display will show a histogram of the automatically determined region of interest for each channel. The region will contain the observed mean value and will have a width as a function of the distribution (up to 1023 bins).



In the case of the TC890 the upper right part of the display shows red/green status indicators for the internal and external memory buffers. If the left button is RED it means that there is an overflow in that buffer. If the right button is RED it means that there was an overflow at some point in the past. The reset button will clear this indicator.

4.2.2. TimeLine Display

Here the histograms of the recorded time values on all channels are superposed. The narrow upper window can be zoomed as desired in the larger lower window. The vertical slider controls the horizontal zoom factor and the horizontal slider will be activated when needed to control the time position of the zoomed portion. The table on the left edge gives basic statistics for each of the channels; the *Mean* and standard *Dev* are given in ns.



4.2.3. Top Line Menu Options & Controls

The File and View options allow pull down choices which can also be accessed by the icon buttons:



Record activates a mode in which all of the measurements are saved in a file. At each activation a file name and destination can be chosen. You can choose between .txt or .xls. The file will be finalized when the mode is de-activated.



Control reactivates the Timer Control window if it has been closed.



Histograms will display a histogram of the accumulated data for each of the channels..



TimeLine will create a single histogram superposing the data for each of the channels.



Marker will display the data stream of hits and markers, in the last acquisition taken, for a TC890.



Reset clears the data once from all of the histograms.



AutoReset clears the data from all of the histograms every time before starting a new acquisition.

4.3. Interpreting the Record File

A TC840 record of an acquisition is shown below:

Instrument TC840 (SN19439)

Acquisition 20060522T073220

ReadParam 023C6BD8 479232 59904 3 0

DataDesc 023C6BD8 12 8 0

0 5.25

1 -

2 -

3 -

4 -

5 -

6 -

7 -

8 -

9 -

10 -

11 -

Here is a fragment of a TC890 file. It shows two hits on channel 1 in the fourth acquisition.

```
# Instrument TC890 (SN19425)
# Acquisition 20060520T160712
# ReadParam 05D70020 8388608 2097152 0 1
# DataDesc 05D70020 103 4 3
0       0       1
0       0       2
0       0       3
0       0       4
1       0       268435
1       0       399933
0       0       5
0       0       6
0       0       7
0       0       8
7       1       1
```

Notes:

- The time stamp of the acquisition is expressed in GMT
- Each non-comment line is the decoding of a single 32-bit word of the transferred data.
- The first column indicates whether the line is a hit header, marker, or channel data item.
- The second column can indicate a memory overflow condition.
- The third column is one of the event number, the time value, or the marker value.
- The last line is a marker showing that the bank switch occurred.

.

5. Errors in Time Difference Measurements

This section will discuss rough calculations of upper limit error estimation of the 95% (+/- 2 sigma) confidence interval for time interval measurements with Agilent Time-to-Digital Converters. It is intended to give limits that will be useable when modules are replaced or repaired. If better error estimation is required it should be clear that the actual characteristics of each channel involved should be quantified. This becomes particularly important for the U1050A-002 with its extremely fine granularity.

The single most important contributor to the error is often the internal time base of the TDC. It can be replaced as desired with an external reference of the desired accuracy.

The TDC's are intended to be used on standardized logic levels as opposed to analog signals. One of the best approaches to controlling the errors is to use rising and falling transitions with the same absolute slew rate and to set trigger thresholds corresponding to the 50% level on the signals of interest. Slew rates ~ 1 V/ns (or better) and logic levels with at least 0.5 Vp-p help produce good results on the U1050A-001 and the U1051A.

A detailed discussion of the error estimation can start with a decomposition of the overall error into various contributions as shown below:

$$OverallTimeDifferenceError = \sqrt{(TimebaseError)^2 + (IntervalStartError)^2 + (IntervalStopError)^2 + (\Delta FGI)^2}$$

It may be more appropriately pessimistic to add the errors linearly as opposed to adding them in quadrature as shown here.

The interval to be measured can fall into one of the following categories:

- Δt between interval start on COM IN to interval stop on any input channel
- Δt between the interval start given by a trigger stop of an input channel to the interval stop given by a trigger stop of a different input channel
- Δt for an interval defined by a pair of trigger stops with the same slope on a single input channel (U1051A only).
- Δt for an interval defined by a pair of trigger stops with different slopes on a single input channel (U1051A only).

Depending on the type of measurement being done some of the error terms can be omitted. For example,

- When measuring averaged time differences over many events the *IntervalErrors* noise contributions drop out.
- When measuring differences between values measured at different times with the same channel and setup on the channel the trigger threshold error will drop out.

Thus, you are encouraged to understand the details of your measurement and carefully choose the error terms to be included/excluded from your analysis.

5.1. Time Base Error

This is the error contribution of the reference clock.

$$TimebaseError = MeasuredTime \times ClockAccuracy$$

MeasuredTime is the actual time measured between the interval start hit and its stop hit.

ClockAccuracy is the stability of the 10 MHz reference clock. In case the internal 10 MHz reference clock is being used, the warranted Clock Accuracy of the U1050A and U1051A TDC's is 2 ppm (2×10^{-6}).

NOTE: This provides a demonstration of the difference between specifying the error when one changes units as opposed to the error that a particular unit is actually limited by. In a specific case it might be easy to reduce this error contribution by indirectly measuring the internal clock's frequency.

5.2. Interval start and stop errors

The interval edge errors can be decomposed into two parts:

- A part determined by noise in the signal and the TDC. This will be independent for the start and the stop.

$$IntervalEdgeError_{NOISE} = \frac{2 \cdot \sqrt{(E_{Signal})^2 + (E_{Input})^2}}{InputSignalSlewRateAtEdgePosition}$$

The error of an interval edge time is a function of the RMS noise of the input signal, the RMS noise of the TDC input, and the signal slew rate at the edge. E_{Signal} is the RMS noise value of the signal filtered by the input circuit of the TDC. A reasonable approximation is to consider that the user signal is filtered by a boxcar filter of 1 GHz noise bandwidth. The noise spectral density of the source E_{Signal} should be integrated in a 0 to 1 GHz frequency band to get the RMS value of the noise. Alternatively, it can be estimated from the noise observed in oscilloscope or digitizer data from a 1 GHz bandwidth instrument. Of course, the intrinsic noise of that instrument must be removed.

The RMS input noise of the TDC can be approximated by $E_{Input} \approx 50\mu V$.

The *InputSignalSlewRate* can also be measured with an oscilloscope or digitizer. Again, the measured slew rate must be corrected for the intrinsic rise time of the instrument used.

The error at the edge point can be minimized with a low noise input signal and a fast slew rate at the trigger level.

- A part determined by edge threshold uncertainties.

  To simplify the treatment we set the $IntervalStartEdgeError_{LEVEL} = 0$

  and put the entire effect into the

$$IntervalStopEdgeError_{LEVEL} = \frac{ThresholdError}{InputSignalSlewRateAtEdgePosition}$$

The *ThresholdError* will depend on the measurement categories introduced earlier.

- 15 mV for the interval start on COM IN to interval stop on any input channel
- 15 mV – for the interval start given by a trigger stop of an input channel to the interval stop given by a trigger stop of a different input channel
- 0 - for an interval defined by a pair of trigger stops with the same slope on a single input channel (U1051A only).
- 15 mV - for an interval defined by a pair of trigger stops with different slopes on a single input channel (U1051A only).

For all cases where different slopes are used for the start and stop edges the time interval measurement can be improved by removing the systematic associated with the trigger hysteresis. The time of the negative edge will be increased by a time $\frac{Hysteresis}{InputSignalSlewRateAtEdgePosition}$. The nominal value of the hysteresis is 15 mV.

Again a detailed study of a particular channels *in situ* behavior should allow a considerable improvement on the above values.

5.3. ΔFGI - Fine grained interpolator error

This is the error contribution from the fine grained interpolator due to several possible sources including Integral Nonlinearity, INL, and Differential Nonlinearity, DNL, effects in the ADC used to digitize the edge signals.

ΔFGI = 80 ps for TC840 and TC890

= 20 ps for TC842

For the TC840 or TC890, 80 ps is the maximum timing error we can expect in single hit measurements. If many measurements are made they will automatically sample the full spectrum of fine grain interpolator values since the experimental signals are not correlated with the 200 MHz coarse grained clock. For example, if all other contributions were zero, it means that for a single measurement giving a 1 μs time interval between the start and stop hits, it is very likely that the effective time interval is bound between 0.99992 μs and 1.00008 μs.

5.4. Example:

Two signals with the following characteristics are connected to the TC840 and a 100 μs interval in the first category above is to be measured using the internal clock.

- rise time$_{10\text{-}90}$ 1 ns

- E_{Signal} 5 mV_{rms}
- Amplitude 1.25 V
- $\Delta V_{10\text{-}90}$ 0.8 x 1.25 V = 1 V
- Slew Rate $\Delta V_{10\text{-}90}$ / rise $time_{10\text{-}90}$ = 1 V/ns

$$TimebaseError = 100\,\mu s \times 2\,ppm$$
$$= 200\,ps$$

$$IntervalStartError = \frac{2 \cdot \sqrt{(E_{Input})^2 + (E_{Signal})^2}}{InputSignalSlewRateAtEdgePosition}$$

$$= \frac{2 \cdot \sqrt{(50\mu V)^2 + (5mV)^2}}{1V / ns}$$
$$= 10\,ps$$

$$IntervalStopError = \frac{\sqrt{4 \cdot (E_{Input})^2 + 4 \cdot (E_{Signal})^2 + (ThresholdError)^2}}{InputSignalSlewRateAtEdgePosition}$$

$$= \frac{\sqrt{4 \cdot (50\mu V)^2 + 4 \cdot (5mV)^2 + (15mV)^2}}{1V / ns}$$
$$= 18\,ps$$

$$\Delta FGI = 80\,ps$$

Combining all of these terms in quadrature then gives

$$OverallTimeDifferenceError = 200\,ps \oplus 10\,ps \oplus 18\,ps \oplus 80\,ps$$
$$= 216\,ps$$

In this case the Interval Errors are not important because of the high slew rate. On the other hand, a better time reference would clearly reduce the error. However, if the interval to be measured were ~20 μs this would not be useful and the linearity characteristics would give the dominant contribution.

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