ARTISAN®
TECHNOLOGY GROUP

Your **definitive** source for quality pre-owned equipment.

Artisan Technology Group
(217) 352-9330 | sales@artisantg.com | artisantg.com

Full-service, independent repair center
with experienced engineers and technicians on staff.

We buy your excess, underutilized, and idle equipment
along with credit for buybacks and trade-ins.

Custom engineering
so your equipment works exactly as you specify.

- Critical and expedited services
- In stock / Ready-to-ship
- Leasing / Rentals / Demos
- ITAR-certified secure asset solutions

Expert team | Trust guarantee | 100% satisfaction

All trademarks, brand names, and brands appearing herein are the property of their respective owners.

Find the *National Instruments PCI-6534* at our website: *Click HERE*

DAQ

NI 653*X* User Manual for Traditional NI-DAQ

High-Speed Digital I/O Devices for PCI, PXI, CompactPCI, AT, EISA, and PCMCIA Bus Systems

February 2005
371464D-01

NATIONAL INSTRUMENTS™

Worldwide Technical Support and Product Information

ni.com

National Instruments Corporate Headquarters

11500 North Mopac Expressway Austin, Texas 78759-3504 USA Tel: 512 683 0100

Worldwide Offices

Australia 1800 300 800, Austria 43 0 662 45 79 90 0, Belgium 32 0 2 757 00 20, Brazil 55 11 3262 3599, Canada 800 433 3488, China 86 21 6555 7838, Czech Republic 420 224 235 774, Denmark 45 45 76 26 00, Finland 385 0 9 725 725 11, France 33 0 1 48 14 24 24, Germany 49 0 89 741 31 30, India 91 80 51190000, Israel 972 0 3 6393737, Italy 39 02 413091, Japan 81 3 5472 2970, Korea 82 02 3451 3400, Lebanon 961 0 1 33 28 28, Malaysia 1800 887710, Mexico 01 800 010 0793, Netherlands 31 0 348 433 466, New Zealand 0800 553 322, Norway 47 0 66 90 76 60, Poland 48 22 3390150, Portugal 351 210 311 210, Russia 7 095 783 68 51, Singapore 1800 226 5886, Slovenia 386 3 425 4200, South Africa 27 0 11 805 8197, Spain 34 91 640 0085, Sweden 46 0 8 587 895 00, Switzerland 41 56 200 51 51, Taiwan 02 2377 2222, Thailand 662 992 7519, United Kingdom 44 0 1635 523545

For further support information, refer to the *Technical Support and Professional Services* appendix. To comment on National Instruments documentation, refer to the National Instruments Web site at ni.com/info and enter the info code feedback.

© 1997–2005 National Instruments Corporation. All rights reserved.

Important Information

Warranty

The NI AT-DIO-32HS, NI DAQCard-6533 for PCMCIA, NI PCI-6534, NI PCI-DIO-32HS, NI PXI-6533, and NI PXI-6534 devices are warranted against defects in materials and workmanship for a period of one year from the date of shipment, as evidenced by receipts or other documentation. National Instruments will, at its option, repair or replace equipment that proves to be defective during the warranty period. This warranty includes parts and labor.

The media on which you receive National Instruments software are warranted not to fail to execute programming instructions, due to defects in materials and workmanship, for a period of 90 days from date of shipment, as evidenced by receipts or other documentation. National Instruments will, at its option, repair or replace software media that do not execute programming instructions if National Instruments receives notice of such defects during the warranty period. National Instruments does not warrant that the operation of the software shall be uninterrupted or error free.

A Return Material Authorization (RMA) number must be obtained from the factory and clearly marked on the outside of the package before any equipment will be accepted for warranty work. National Instruments will pay the shipping costs of returning to the owner parts which are covered by warranty.

National Instruments believes that the information in this document is accurate. The document has been carefully reviewed for technical accuracy. In the event that technical or typographical errors exist, National Instruments reserves the right to make changes to subsequent editions of this document without prior notice to holders of this edition. The reader should consult National Instruments if errors are suspected. In no event shall National Instruments be liable for any damages arising out of or related to this document or the information contained in it.

EXCEPT AS SPECIFIED HEREIN, NATIONAL INSTRUMENTS MAKES NO WARRANTIES, EXPRESS OR IMPLIED, AND SPECIFICALLY DISCLAIMS ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. CUSTOMER'S RIGHT TO RECOVER DAMAGES CAUSED BY FAULT OR NEGLIGENCE ON THE PART OF NATIONAL INSTRUMENTS SHALL BE LIMITED TO THE AMOUNT THERETOFORE PAID BY THE CUSTOMER. NATIONAL INSTRUMENTS WILL NOT BE LIABLE FOR DAMAGES RESULTING FROM LOSS OF DATA, PROFITS, USE OF PRODUCTS, OR INCIDENTAL OR CONSEQUENTIAL DAMAGES, EVEN IF ADVISED OF THE POSSIBILITY THEREOF. This limitation of the liability of National Instruments will apply regardless of the form of action, whether in contract or tort, including negligence. Any action against National Instruments must be brought within one year after the cause of action accrues. National Instruments shall not be liable for any delay in performance due to causes beyond its reasonable control. The warranty provided herein does not cover damages, defects, malfunctions, or service failures caused by owner's failure to follow the National Instruments installation, operation, or maintenance instructions; owner's modification of the product; owner's abuse, misuse, or negligent acts; and power failure or surges, fire, flood, accident, actions of third parties, or other events outside reasonable control.

Copyright

Under the copyright laws, this publication may not be reproduced or transmitted in any form, electronic or mechanical, including photocopying, recording, storing in an information retrieval system, or translating, in whole or in part, without the prior written consent of National Instruments Corporation.

Trademarks

National Instruments, NI, ni.com, and LabVIEW are trademarks of National Instruments Corporation. Refer to the *Terms of Use* section on `ni.com/legal` for more information about National Instruments trademarks.

Other product and company names mentioned herein are trademarks or trade names of their respective companies.

Members of the National Instruments Alliance Partner Program are business entities independent from National Instruments and have no agency, partnership, or joint-venture relationship with National Instruments.

Patents

For patents covering National Instruments products, refer to the appropriate location: **Help»Patents** in your software, the `patents.txt` file on your CD, or `ni.com/patents`.

WARNING REGARDING USE OF NATIONAL INSTRUMENTS PRODUCTS

(1) NATIONAL INSTRUMENTS PRODUCTS ARE NOT DESIGNED WITH COMPONENTS AND TESTING FOR A LEVEL OF RELIABILITY SUITABLE FOR USE IN OR IN CONNECTION WITH SURGICAL IMPLANTS OR AS CRITICAL COMPONENTS IN ANY LIFE SUPPORT SYSTEMS WHOSE FAILURE TO PERFORM CAN REASONABLY BE EXPECTED TO CAUSE SIGNIFICANT INJURY TO A HUMAN.

(2) IN ANY APPLICATION, INCLUDING THE ABOVE, RELIABILITY OF OPERATION OF THE SOFTWARE PRODUCTS CAN BE IMPAIRED BY ADVERSE FACTORS, INCLUDING BUT NOT LIMITED TO FLUCTUATIONS IN ELECTRICAL POWER SUPPLY, COMPUTER HARDWARE MALFUNCTIONS, COMPUTER OPERATING SYSTEM SOFTWARE FITNESS, FITNESS OF COMPILERS AND DEVELOPMENT SOFTWARE USED TO DEVELOP AN APPLICATION, INSTALLATION ERRORS, SOFTWARE AND HARDWARE COMPATIBILITY PROBLEMS, MALFUNCTIONS OR FAILURES OF ELECTRONIC MONITORING OR CONTROL DEVICES, TRANSIENT FAILURES OF ELECTRONIC SYSTEMS (HARDWARE AND/OR SOFTWARE), UNANTICIPATED USES OR MISUSES, OR ERRORS ON THE PART OF THE USER OR APPLICATIONS DESIGNER (ADVERSE FACTORS SUCH AS THESE ARE HEREAFTER COLLECTIVELY TERMED "SYSTEM FAILURES"). ANY APPLICATION WHERE A SYSTEM FAILURE WOULD CREATE A RISK OF HARM TO PROPERTY OR PERSONS (INCLUDING THE RISK OF BODILY INJURY AND DEATH) SHOULD NOT BE RELIANT SOLELY UPON ONE FORM OF ELECTRONIC SYSTEM DUE TO THE RISK OF SYSTEM FAILURE. TO AVOID DAMAGE, INJURY, OR DEATH, THE USER OR APPLICATION DESIGNER MUST TAKE REASONABLY PRUDENT STEPS TO PROTECT AGAINST SYSTEM FAILURES, INCLUDING BUT NOT LIMITED TO BACK-UP OR SHUT DOWN MECHANISMS. BECAUSE EACH END-USER SYSTEM IS CUSTOMIZED AND DIFFERS FROM NATIONAL INSTRUMENTS' TESTING PLATFORMS AND BECAUSE A USER OR APPLICATION DESIGNER MAY USE NATIONAL INSTRUMENTS PRODUCTS IN COMBINATION WITH OTHER PRODUCTS IN A MANNER NOT EVALUATED OR CONTEMPLATED BY NATIONAL INSTRUMENTS, THE USER OR APPLICATION DESIGNER IS ULTIMATELY RESPONSIBLE FOR VERIFYING AND VALIDATING THE SUITABILITY OF NATIONAL INSTRUMENTS PRODUCTS WHENEVER NATIONAL INSTRUMENTS PRODUCTS ARE INCORPORATED IN A SYSTEM OR APPLICATION, INCLUDING, WITHOUT LIMITATION, THE APPROPRIATE DESIGN, PROCESS AND SAFETY LEVEL OF SUCH SYSTEM OR APPLICATION.

Compliance

Compliance with FCC/Canada Radio Frequency Interference Regulations

Determining FCC Class

The Federal Communications Commission (FCC) has rules to protect wireless communications from interference. The FCC places digital electronics into two classes. These classes are known as Class A (for use in industrial-commercial locations only) or Class B (for use in residential or commercial locations). All National Instruments (NI) products are FCC Class A products.

Depending on where it is operated, this Class A product could be subject to restrictions in the FCC rules. (In Canada, the Department of Communications (DOC), of Industry Canada, regulates wireless interference in much the same way.) Digital electronics emit weak signals during normal operation that can affect radio, television, or other wireless products.

All Class A products display a simple warning statement of one paragraph in length regarding interference and undesired operation. The FCC rules have restrictions regarding the locations where FCC Class A products can be operated.

Consult the FCC Web site at `www.fcc.gov` for more information.

FCC/DOC Warnings

This equipment generates and uses radio frequency energy and, if not installed and used in strict accordance with the instructions in this manual and the CE marking Declaration of Conformity*, may cause interference to radio and television reception. Classification requirements are the same for the Federal Communications Commission (FCC) and the Canadian Department of Communications (DOC).

Changes or modifications not expressly approved by NI could void the user's authority to operate the equipment under the FCC Rules.

Class A

Federal Communications Commission

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user is required to correct the interference at their own expense.

Canadian Department of Communications

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Cet appareil numérique de la classe A respecte toutes les exigences du Règlement sur le matériel brouilleur du Canada.

Compliance with EU Directives

Users in the European Union (EU) should refer to the Declaration of Conformity (DoC) for information* pertaining to the CE marking. Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

* The CE marking Declaration of Conformity contains important supplementary information and instructions for the user or installer.

Conventions

The following conventions appear in this manual:

<>	Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, DIO<3..0>.
»	The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.
♦	The ♦ symbol indicates that the following text applies only to a specific product, a specific operating system, or a specific software version.
	This icon denotes a tip, which alerts you to advisory information.
	This icon denotes a note, which alerts you to important information.
	This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash. When this symbol is marked on a product, refer to the for information about precautions to take.
bold	Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names.
italic	Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font also denotes text that is a placeholder for a word or value that you must supply.
`monospace`	Text in this font denotes text or characters that you should enter from the keyboard. This font is also used for the proper names of functions, variables, and filenames and extensions.
NI 6533	NI 6533 refers to the NI AT-DIO-32HS, NI DAQCard-6533 for PCMCIA, NI PCI-DIO-32HS, and NI PXI-6533 devices, unless otherwise noted.
NI 6534	NI 6534 refers to the NI PCI-6534 and NI PXI-6534 devices, unless otherwise noted.
NI 653*X*	NI 653*X* refers to the NI AT-DIO-32HS, NI DAQCard-6533 for PCMCIA, NI PCI-6534, NI PCI-DIO-32HS, NI PXI-6533, and NI PXI-6534 devices, unless otherwise noted.

Contents

Chapter 1
Getting Started with Your NI 653*X*

NI 653*X* Overview 1-1
Control Lines 1-2
What You Need to Get Started 1-2
Choosing Your Programming Software 1-3
National Instruments Application Software 1-3
NI-DAQ Driver Software 1-4
Installing Your Software 1-6
Unpacking Your NI 653*X* 1-6
Installing Your NI 653*X* 1-7
Installing the NI PCI-DIO-32HS, NI PCI-6534, or NI PCI-7030/6533 1-7
Installing the NI PXI-6533, NI PXI-6534, or NI PXI-7030/6533 1-7
Installing the NI AT-DIO-32HS 1-8
Installing the NI DAQCard-6533 for PCMCIA 1-9
Configuring the NI 653*X* 1-9
In Windows 1-9
In Mac OS 1-10
Safety Information 1-10

Chapter 2
Using Your NI 653*X*

Choosing the Correct Mode for Your Application 2-1
Controlling and Monitoring Static Digital Lines—Unstrobed I/O 2-2
Configuring Digital Lines 2-2
Standard Output 2-2
Open-Collector Output 2-2
Using Control Lines as Extra Unstrobed Data Lines 2-3
Connecting Signals 2-4
Creating a Program 2-4
Programming the Control/Timing Lines as Extra Unstrobed Data Lines 2-5
Generating and Receiving Digital Patterns and Waveforms—Pattern I/O 2-6
Deciding the Width of Data to Transfer 2-6
Deciding Transfer Direction 2-7
Choosing an Internal or External REQ Source 2-7
Reversing the REQ Polarity 2-7
Specifying the Transfer Rate 2-8

Starting and Stopping Data Transfer—Triggering ... 2-8
Start and Stop Trigger ... 2-9
Choosing Continuous or Finite Data Transfer ... 2-11
Finite Transfers ... 2-11
Continuous Input ... 2-11
Continuous Output ... 2-11
Choosing DMA or Interrupt Transfers ... 2-12
Monitoring Data Transfer ... 2-12
Connecting Signals ... 2-13
Creating a Program ... 2-14
Transferring Data Between Two Devices—Handshaking I/O ... 2-17
Choosing the Width of Data to Transfer ... 2-17
Deciding Data Transfer Direction ... 2-17
Deciding Which Handshaking Protocol to Use ... 2-17
Using the Burst Protocol ... 2-18
Deciding the PCLK Signal Direction ... 2-18
Selecting ACK/REQ Signal Polarity ... 2-19
Choosing Whether to Use a Programmable Delay ... 2-19
Choosing Continuous or Finite Data Transfer ... 2-20
Finite Transfers ... 2-20
Continuous Input ... 2-20
Continuous Output ... 2-20
Choosing DMA or Interrupt Transfers ... 2-21
Connecting Signals ... 2-21
Choosing the Startup Sequence ... 2-22
Using an Initialization Order ... 2-22
Controlling Line Polarities ... 2-23
Creating a Program ... 2-23
Monitoring Line State—Change Detection ... 2-28
Deciding the Width of Data to Acquire ... 2-28
Deciding Which Lines You Want to Monitor ... 2-29
Deciding How to Start and Stop Data Transfer—Triggering ... 2-30
Start and Stop Trigger ... 2-31
Choosing Continuous or Finite Data Transfer ... 2-32
Finite Transfers ... 2-32
Continuous Input ... 2-32
Choosing DMA or Interrupt Transfers ... 2-33
Connecting Signals ... 2-33
Creating a Program ... 2-33

Chapter 3
Timing Diagrams

Pattern I/O Timing Diagrams 3-1
Internal REQ Signal Source 3-1
External REQ Signal Source 3-2
Handshaking I/O Timing Diagrams 3-4
Comparing the Different Handshaking Protocols 3-4
Using the Burst Protocol 3-5
Using Asynchronous Protocols 3-11
Using the 8255-Emulation Protocol 3-11
Using the Level-ACK Protocol 3-17
Using Protocols Based on Signal Edges 3-22
Using the Trailing-Edge Protocol 3-22

Appendix A
Specifications

Appendix B
Using PXI with CompactPCI

Appendix C
Connecting Signals with Accessories

Appendix D
Hardware Considerations

Appendix E
Optimizing Your Transfer Rates

Appendix F
Technical Support and Professional Services

Glossary

Index

1

Getting Started with Your NI 653*X*

The *NI 653X User Manual* describes installing, configuring, setting up, and programming applications for the NI 653*X* family of digital I/O (DIO) devices. The NI 653*X* family includes the NI AT-DIO-32HS, NI DAQCard-6533 for PCMCIA, NI PCI-6534, NI PCI-DIO-32HS, NI PXI-6533, NI PXI-6534, and NI PCI/PXI-7030/6533.

NI 653*X* Overview

With NI 653*X* devices, you can use your computer or chassis as a digital I/O tester, logic analyzer, or system controller for laboratory testing, production testing, and industrial process monitoring and control.

Each NI 653*X* provides 32 digital data lines that are individually configurable as input or output, grouped into four 8-bit ports. Each line can sink or source 24 mA of current.

The NI 6534 contains onboard memory, enabling you to transfer data to/from this memory at a guaranteed rate. This memory removes the dependency on the host computer bus for applications that require guaranteed transfer rates.

The NI PCI/PXI-7030/6533 is an RT Series device that contains a processor board (NI 7030), an NI 6533 daughter board, and an independent processor that runs LabVIEW Real-Time applications. The NI 6533 daughter board contains all the features and functions of the NI PCI/PXI-6533 described in this manual. For more information about your NI PCI/PXI-7030/6533, refer to the *RT Series DAQ Device User Manual*.

The NI 6534 uses the Real-Time System Integration (RTSI) bus to easily synchronize several measurement devices to a common trigger or timing event. The RTSI bus allows synchronization of the measurements. The RTSI bus consists of the RTSI bus interface and a ribbon cable to route timing and trigger signals between as many as five DAQ devices in the

computer. If you are using the NI PXI-6534 or NI PXI-6533 in a PXI chassis, RTSI lines, known as the PXI trigger bus, are part of the backplane. In addition, a phase-locked loop (PLL) circuit accomplishes the synchronization of multiple NI PXI-6534 devices or other PXI devices which support PLL synchronization by allowing these devices to all lock to the same reference clock present on the PXI backplane. Refer to the *Phase-Locked Loop Circuit (NI PXI-6534 Only)* section of Appendix D, *Hardware Considerations*, for more information.

Detailed NI 653*X* specifications are in Appendix A, *Specifications*.

Control Lines

In addition to controlling and monitoring relay-type applications, the NI 653*X* also provides two timing/handshaking controllers, named Group 1 and Group 2, for high-speed data transfer. Refer to the *Using Control Lines as Extra Unstrobed Data Lines* section of Chapter 2, *Getting Started with Your NI 653X*, for more information about the capabilities of these control lines.

What You Need to Get Started

To begin using your NI 653*X*, you need the following items:

- ❑ One or more of the following devices:
  - NI AT-DIO-32HS
  - NI DAQCard-6533 for PCMCIA
  - NI PCI-6534
  - NI PCI-DIO-32HS
  - NI PXI-6533
  - NI PXI-6534
  - NI PCI/PXI-7030/6533 (RT Series DAQ device)
- ❑ *NI 653X User Manual*
- ❑ NI-DAQ (for PC compatibles or Mac OS)
- ❑ Software environments supported by NI-DAQ (optional):
  - LabVIEW (for Windows or Mac OS)
  - LabVIEW Real-Time Module (LabVIEW RT)
  - LabWindows™/CVI™ (for Windows or Mac OS)

  - Measurement Studio (for Windows only)
  - Other supported compilers

- ❑ The appropriate signal connector
- ❑ The appropriate shielded or ribbon cable. Refer to Appendix C, *Connecting Signals with Accessories*, for specific information about cables that are compatible with your device.
- ❑ Your computer or PXI/CompactPCI chassis and controller

Choosing Your Programming Software

When programming NI measurement hardware, you can use either NI application software or another application development environment (ADE).

National Instruments Application Software

LabVIEW and LabVIEW RT feature interactive graphics, a state-of-the-art user interface, and a powerful graphical programming language. The LabVIEW Data Acquisition VI Library, a series of virtual instruments (VIs) for using LabVIEW with National Instruments DAQ hardware, is included with LabVIEW. The LabVIEW Data Acquisition VI Library is functionally equivalent to the NI-DAQ application programming interface (API).

As with LabVIEW, you develop your LabVIEW RT applications with graphical programming, then download the program to run on an independent hardware target with a real-time operating system. LabVIEW RT allows you to use the NI 6533 digital DAQ devices in two configurations: the NI PCI/PXI-7030/6533, and the NI PXI-6533 in a PXI system being controlled in real time by LabVIEW RT.

LabWindows/CVI is a complete ANSI C ADE that features an interactive user interface, code generation tools, and the LabWindows/CVI Data Acquisition and Easy I/O libraries.

Measurement Studio, which includes tools for Visual C++ and tools for Visual Basic, is a development suite that allows you to design test and measurement applications. For Visual Basic developers, Measurement Studio features a set of ActiveX controls for using National Instruments DAQ hardware. These ActiveX controls provide a high-level programming interface for building VIs. For Visual C++ developers, Measurement Studio

offers a set of Visual C++ classes and tools to integrate those classes into Visual C++ applications. The ActiveX controls and classes are available with Measurement Studio and the NI-DAQ software.

Using LabVIEW, LabWindows/CVI, or Measurement Studio greatly reduces the development time for your data acquisition and control application.

NI-DAQ Driver Software

The NI-DAQ driver software shipped with your NI 653*X* has an extensive library of functions that you can call from your ADE. These functions allow you to use all the features of the NI 653*X*.

NI-DAQ carries out many of the complex interactions, such as programming interrupts, between the computer and the DAQ hardware. NI-DAQ maintains a consistent software interface among its different versions so that you can change platforms with minimal modifications to your code. Whether you are using LabVIEW, LabWindows/CVI, Measurement Studio, or another ADE, your application uses the NI-DAQ driver software, as illustrated in Figure 1-1.

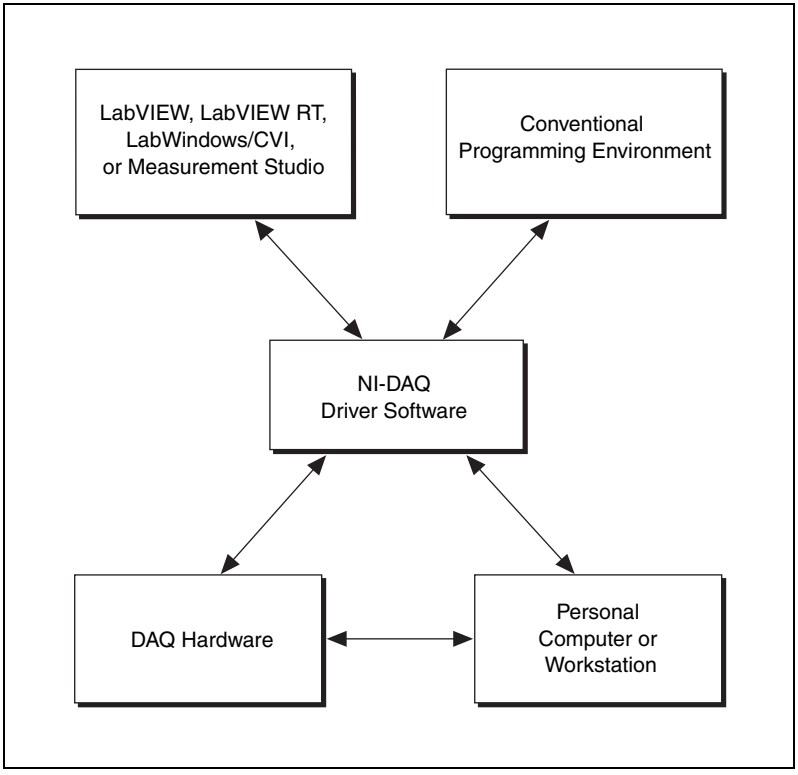


Figure 1-1. The Relationship Between the Programming Environment, NI-DAQ, and Your Hardware

To download a free copy of the most recent version of NI-DAQ, click **Drivers and Updates** at `ni.com/downloads`. Use the following table to find which NI-DAQ versions are compatible with your device.

Table 1-1. NI 653X Devices and NI-DAQ Support

Device Supported	NI-DAQ Version	
	Windows	Mac
NI PCI-DIO-32HS	Version 5.0 or later	Version 6.1.0 or later
NI AT-DIO-32HS	Version 5.0 or later	N/A
NI PXI-6533	Version 5.1 or later	Version 6.1.3 or later
NI DAQCard-6533 for PCMCIA	Version 5.1 or later	Version 6.1.0 or later
NI PXI-6534	Version 6.9 or later	N/A

Table 1-1. NI 653X Devices and NI-DAQ Support (Continued)

Device Supported	NI-DAQ Version	
	Windows	Mac
NI PCI-6534	Version 6.9 or later	N/A
NI PCI or PXI-7030/6533	Version 6.5.2 or later	N/A

Installing Your Software

Install application development software, such as LabVIEW or LabWindows/CVI, according to instructions on the CD and the release notes. If NI-DAQ was not installed with your ADE, then install NI-DAQ according to the instructions on the CD and the *DAQ Quick Start Guide* included with your device.

Note It is important to install NI-DAQ before installing your device(s) to ensure the device(s) are properly detected.

Unpacking Your NI 653*X*

Your NI 653*X* is shipped in an antistatic package to prevent electrostatic damage to the device. To avoid such damage in handling the device, take the following precautions:

- Ground yourself using a grounding strap or by holding a grounded object.
- Touch the antistatic package to a metal part of your computer chassis before removing the device from the package.

Caution *Never* touch the exposed pins of connectors to prevent electrostatic discharge from damaging the device.

Remove the device from the package and inspect the device for loose components or any sign of damage. Notify NI if the device appears damaged in any way. Do *not* install a damaged device into your computer.

Store your NI 653*X* in the antistatic envelope when not in use.

Installing Your NI 653*X*

The following are general installation instructions. Consult your computer or chassis user manual or technical reference manual for specific instructions and warnings about installing new devices.

Note It is important to install NI-DAQ before installing your device(s) to ensure the device(s) are properly detected.

Installing the NI PCI-DIO-32HS, NI PCI-6534, or NI PCI-7030/6533

You can install an NI PCI-DIO-32HS, NI PCI-6534, or NI PCI-7030/6533 in any available PCI expansion slot in your computer.

1. Power off and unplug your computer.
2. Remove the cover.
3. Remove the expansion slot cover on the back panel of the computer.
4. Touch a metal part of your computer chassis to discharge any static electricity that might be on your clothes or body.
5. Insert the NI 653*X* into a PCI system slot. It may be a tight fit, but do *not* force the device into place.
6. Screw the mounting bracket of the NI 653*X* to the back panel rail of the computer.
7. Visually verify the installation. Make sure the device is not touching other boards or components and is inserted fully in the slot.
8. Replace the cover of your computer.
9. Plug in and power on your computer.

You are now ready to configure your NI 653*X*.

Installing the NI PXI-6533, NI PXI-6534, or NI PXI-7030/6533

You can install an NI PXI-653*X* or NI PXI-7030/6533 any available 5 V peripheral slot in your PXI or CompactPCI chassis.

Note Your PXI device has connections to several reserved lines on the CompactPCI J2 connector. Before installing a PXI device in a CompactPCI system that uses J2 connector lines for purposes other than PXI, refer to Appendix C, *Connecting Signals with Accessories*.

1. Power off and unplug your PXI or CompactPCI chassis.
2. Choose an unused PXI or CompactPCI 5 V peripheral slot.



Tip For maximum performance of your CompactPCI system, install the NI PXI-653*X* in a slot that supports bus arbitration or bus-master cards. The NI PXI-653*X* contains onboard bus-master direct memory access (DMA) logic that can operate only in such a slot. If you install the device in a slot that does not support bus masters, you must disable the NI PXI-653*X* onboard DMA controller using your software. PXI-compliant chassis have bus arbitration for all slots.

3. Remove the filler panel for the peripheral slot you have chosen.
4. Touch a metal part on your chassis to discharge any static electricity that might be on your clothes or body.
5. Insert the NI PXI-653*X* into a 5 V slot. Use the injector/ejector handle to fully inject the device into place.
6. Screw the front panel of the NI PXI-653*X* to the front panel mounting rails of the PXI or CompactPCI chassis.
7. Visually verify the installation. Make sure the device is not touching other boards or components and is fully in the slot.
8. Plug in and power on the PXI or CompactPCI chassis.

You are now ready to configure your NI 653*X*.

Installing the NI AT-DIO-32HS

You can install an NI AT-DIO-32HS in any available AT (16-bit ISA) or EISA expansion slot in your computer.

1. Power off and unplug your computer.
2. Remove the cover.
3. Remove the expansion slot cover on the back panel of the computer.
4. Touch a metal part of your computer chassis to discharge any static electricity that might be on your clothes or body.
5. Insert the NI AT-DIO-32HS into an AT (16-bit ISA) or EISA slot. It can be a tight fit, but do *not* force the device into place.
6. Screw the mounting bracket of the NI AT-DIO-32HS to the back panel rail of the computer.
7. Visually verify the installation. Make sure the device is not touching other boards or components and is fully inserted in the slot.

8. Replace the cover of the computer.
9. Plug in and power on your computer.

You are now ready to configure your NI 653*X*.

Installing the NI DAQCard-6533 for PCMCIA

You can install your NI DAQCard-6533 for PCMCIA in any available CardBus-compatible Type II PCMCIA slot. Consult the computer manufacturer for information about slot compatibility.

1. Power off your computer. If your computer and operating system support hot insertion, you may insert or remove the NI DAQCard-6533 at any time, whether the computer is powered on or off.
2. Remove the PCMCIA slot cover on your computer, if any.

You are now ready to configure your NI 653*X*.

Configuring the NI 653*X*

Your NI 653*X* is automatically configured in Measurement & Automation Explorer (MAX), which is installed with NI-DAQ in Windows, or in the NI-DAQ Configuration Utility, which is installed with NI-DAQ in the Mac OS. All settings are initially configured to default settings.

In Windows

If you would like to change or view default settings, complete the following steps, also available in the *DAQ Quick Start Guide*:

1. Launch MAX.
2. Open **Devices and Interfaces**.
3. Right-click the device you want to configure and choose **Properties**.
4. Click the **Test Resources** button to test hardware resources.

To create a virtual channel or to learn about other capabilities of MAX, read the help files available in MAX by selecting **Help»Help Topics**.

In Mac OS

To view and test current resource allocation, complete the following steps:

1. Open the NI-DAQ Configuration Utility.
2. Select the device you want to configure.
3. Click the **Configure** button.
4. Click the **Test Resources** button to test hardware resources.

Caution Do *not* configure the NI 653*X* resources in conflict with non-NI devices. For example, do *not* configure two devices to have the same base address.

Note The NI PCI/PXI-7030/6533 configuration is similar to NI PCI/PXI-653*X* configuration with a few exceptions. Refer to your *RT Series DAQ Device User Manual* for specific configuration details.

Note If you are using the NI AT-DIO-32HS in a non-Plug and Play system, the device automatically configures to a switchless DAQ device so that it can work in the system.

Now that you have completed configuring your device, you can begin setting up the device for use.

Safety Information

The following section contains important safety information that you *must* follow when installing and using the product.

Do *not* operate the product in a manner not specified in this document. Misuse of the product can result in a hazard. You can compromise the safety protection built into the product if the product is damaged in any way. If the product is damaged, return it to National Instruments for repair.

Do *not* substitute parts or modify the product except as described in this document. Use the product only with the chassis, modules, accessories, and cables specified in the installation instructions. You *must* have all covers and filler panels installed during operation of the product.

Do *not* operate the product in an explosive atmosphere or where there may be flammable gases or fumes. If you must operate the product in such an environment, it must be in a suitably rated enclosure.

If you need to clean the product, use a soft, nonmetallic brush. Make sure that the product is completely dry and free from contaminants before returning it to service.

Operate the product only at or below Pollution Degree 2. Pollution is foreign matter in a solid, liquid, or gaseous state that can reduce dielectric strength or surface resistivity. The following is a description of pollution degrees:

- Pollution Degree 1 means no pollution or only dry, nonconductive pollution occurs. The pollution has no influence.
- Pollution Degree 2 means that only nonconductive pollution occurs in most cases. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Pollution Degree 3 means that conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation.

You *must* insulate signal connections for the maximum voltage for which the product is rated. Do *not* exceed the maximum ratings for the product. Do not install wiring while the product is live with electrical signals. Do not remove or add connector blocks when power is connected to the system. Avoid contact between your body and the connector block signal when hot swapping modules. Remove power from signal lines before connecting them to or disconnecting them from the product.

Operate the product at or below the *installation category*[1] marked on the hardware label. Measurement circuits are subjected to *working voltages*[2] and transient stresses (overvoltage) from the circuit to which they are connected during measurement or test. Installation categories establish standard impulse withstand voltage levels that commonly occur in electrical distribution systems. The following is a description of installation categories:

- Installation Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS[3] voltage. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements

[1] Installation categories, also referred to as *measurement categories*, are defined in electrical safety standard IEC 61010-1.

[2] Working voltage is the highest rms value of an AC or DC voltage that can occur across any particular insulation.

[3] MAINS is defined as a hazardous live electrical supply system that powers equipment. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.

include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

- Installation Category II is for measurements performed on circuits directly connected to the electrical distribution system. This category refers to local-level electrical distribution, such as that provided by a standard wall outlet (for example, 115 V for U.S. or 230 V for Europe). Examples of Installation Category II are measurements performed on household appliances, portable tools, and similar product.
- Installation Category III is for measurements performed in the building installation at the distribution level. This category refers to measurements on hard-wired equipment such as equipment in fixed installations, distribution boards, and circuit breakers. Other examples are wiring, including cables, bus-bars, junction boxes, switches, socket-outlets in the fixed installation, and stationary motors with permanent connections to fixed installations.
- Installation Category IV is for measurements performed at the primary electrical supply installation (<1,000V). Examples include electricity meters and measurements on primary overcurrent protection devices and on ripple control units.

2

Using Your NI 653*X*

To begin using your NI 653*X*, navigate this chapter in the following order:

1. Use the table below to choose the correct mode of operation.
2. Follow the instructions for the application you want to perform.
3. Refer to pinout diagrams in Appendix C, *Connecting Signals with Accessories*, when you are ready to connect your devices and/or accessories.

Tip Refer to the glossary for definitions of DIO terms used throughout this chapter.

Choosing the Correct Mode for Your Application

Use the following table to find the correct mode for your application:

Application Requirements	Suggested Mode
I need to perform basic digital I/O that does not need hardware timing or handshaking between the NI 653*X* and the peripheral device.	Unstrobed I/O
I want to individually configure the direction of each bit instead of in groups of eight.	Unstrobed I/O
I want to connect two or more output drivers/pins to the same line.	Unstrobed output with open collector driver
I want to start and/or stop acquiring data upon a trigger and/or to transfer data at timed intervals.	Pattern I/O
I need to communicate with an external device using an exchange of signals to request and acknowledge each data transfer.	Handshaking I/O—Select appropriate protocol
I want the NI 653*X* to capture input data only when certain lines change states.	Change Detection
I want to monitor activity on input lines without continuously polling or transferring unnecessary data during periods of inactivity.	Change Detection

Controlling and Monitoring Static Digital Lines—Unstrobed I/O

This section explains how to control and monitor static digital lines through software-timed reads and writes to and from the digital lines of your NI 653*X*.

Configuring Digital Lines

For unstrobed I/O, the direction of each of the 32 data lines is individually configurable. You can configure each data line as one of the following:

- Input
- Standard output
- Open-collector output

Standard Output

A standard driver drives its output pin to approximately 0 V for logic low, or +5 V for logic high. Using a standard output driver has the following advantages:

- It does not require pull-up resistors.
- It is independent of the state of the DPULL line, which selects whether the 653*X* pulls the data lines high or low when undriven.
- It has high current drive for both its logic high and logic low states.
- It can drive high-speed transitions in both the high-to-low and low-to-high directions.

Open-Collector Output

An open-collector output driver drives its output pin to 0 V for logic low. For logic high, the output driver assumes a high-impedance state and does not drive a voltage. To pull the pin to +5 V for logic high, a pull-up resistor is required.

To provide a pull-up resistor, you can do one of the following things:

- Connect the DPULL pin on the I/O connector to the +5 V pin. This provides 100 kΩ pull-up resistors on all data lines. For more information about CPULL and DPULL, refer to the *Power-On State* section of Appendix D, *Hardware Considerations*.
- Add a resistor to your circuit at the DUT.

Using the open-collector driver has the following advantages:

- It connects two or more open-collector outputs together without damaging the drivers.
- It connects open collector outputs to open-collector drivers, to GND signals, or to switches connecting to GND signals, without damaging the drivers.
- It uses open collector outputs bidirectionally; if you connect open-collector outputs together, you can read back the value of a pin to determine if any connected outputs are logic low.

Using Control Lines as Extra Unstrobed Data Lines

The NI 653*X* has two timing controllers (Group 1 and Group 2) for high-speed data transfer. Each group contains four control lines which can time the input/output of data with hardware precision. You can use Groups 1 and 2 to perform the following actions:

- Generate or receive digital patterns and waveforms at regular intervals or timed by an external TTL signal
- Transfer data between two devices using one of six configurable handshaking protocols
- Acquire digital data every time the state of a data line changes

Note If you configure either group to perform handshaking I/O or pattern I/O, the associated timing control lines for that group are not available for unstrobed I/O.

If you are not using Group 1 and/or Group 2 as timing controllers to perform pattern I/O or handshaking I/O, you can use their control lines as extra data lines. These lines constitute Port 4. The direction and output driver type of these lines are *not* configurable—four lines are used as input only and four are used as standard output only. Even though there are eight actual lines, the port width for Port 4 is 4 bits. In software, these lines are collectively referred to as Port 4. When writing to Port 4, the output lines are affected; and when reading from Port 4, the input lines are read. Table 2-1 displays how Port 4 lines are organized.

Table 2-1. Port 4 Lines

Direction	Line	I/O Pins
Input	0	STOPTRIG 1
	1	STOPTRIG 2
	2	REQ 1
	3	REQ 2
Output (standard)	0	PCLK 1
	1	PCLK 2
	2	ACK 1
	3	ACK 2

Connecting Signals

Connect digital input signals to the I/O connector using the pinout diagrams, Figure C-1, *NI 653X I/O Connector 68-Pin Assignments*, and Figure C-2, *68-to-50-Pin Adapter Pin Assignments*.

Creating a Program

Using the following flowcharts as a guide, create a program to perform unstrobed I/O. Figure 2-1 displays a flowchart for C programming using NI-DAQ, and Figure 2-2 shows a LabVIEW programming flowchart.

The boxes represent function names for the appropriate software, and the diamonds represent decision points.

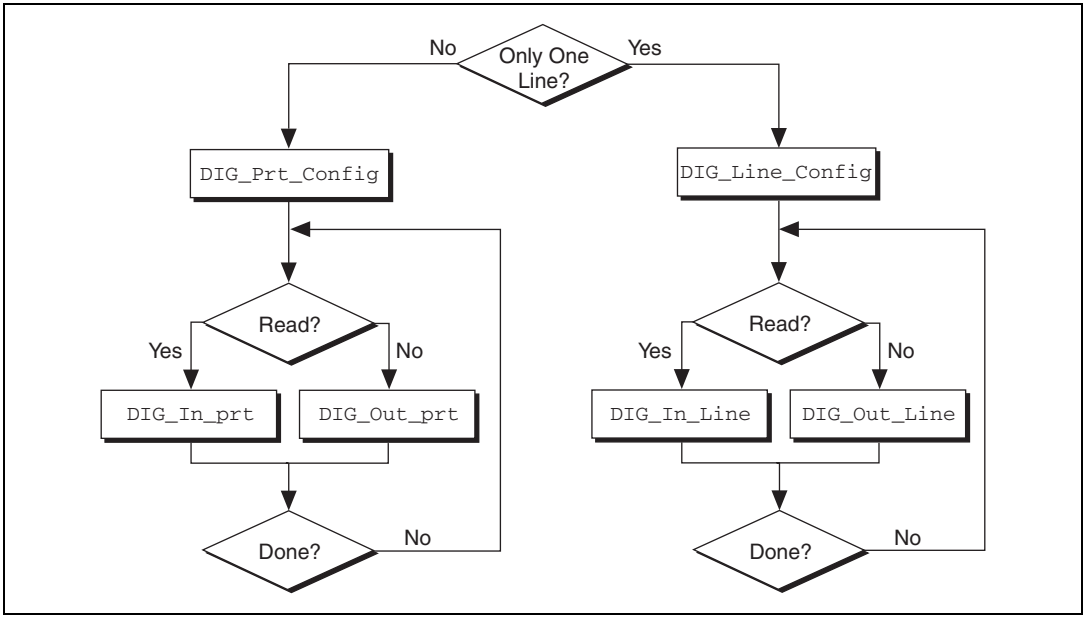


Figure 2-1. Programming Unstrobed I/O in NI-DAQ

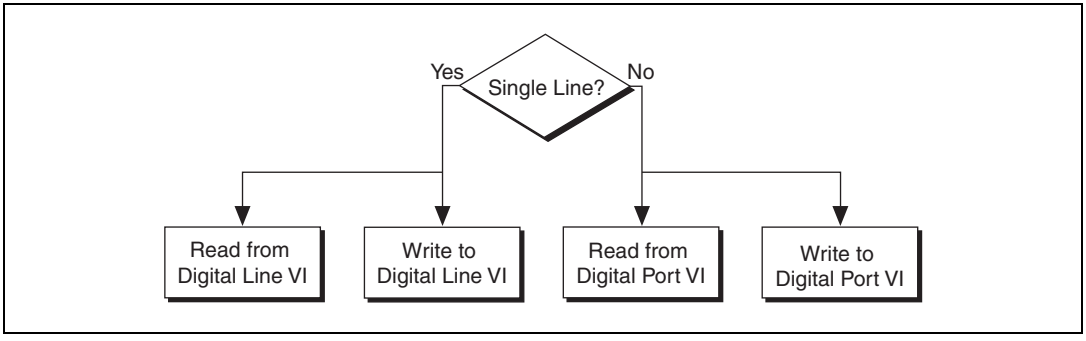


Figure 2-2. Programming Unstrobed I/O in LabVIEW/LabVIEW RT

Programming the Control/Timing Lines as Extra Unstrobed Data Lines

To use the control/timing lines as extra unstrobed data lines:

- NI-DAQ C Interface—If both sets of control/timing lines are available, call `DIG_In_Prt` or `DIG_Out_Prt` and set Port Number to `4`. If both sets of control/timing lines are not available, use `DIG_In_Line` and `DIG_Out_Line` to individually read or write to the appropriate control/timing lines.

- LabVIEW—Use the Easy Digital I/O VI from the following list that is appropriate for your task:
  - Read from Digital Line VI to read from a single line
  - Write to Digital Line VI to write to a single line
  - Read from Digital Port VI to read from a digital port
  - Write to Digital Port VI to write to a digital port

  Set **digital channel** to `4` and **port width** to `4`.

If one control/timing line is used or reserved, and you wish to use some or all of the remaining lines for I/O, use the Advanced Digital I/O VIs DIO Port Read VI or DIO Port Write VI. Set the bits in the **line mask** parameter to the lines to use for I/O.

Generating and Receiving Digital Patterns and Waveforms—Pattern I/O

Using pattern I/O, you can acquire or generate patterns on every rising or falling edge of a clock signal. The clock signal can be generated internally by an onboard 32-bit counter set to a user-specified frequency, or the clock signal can be received from the REQ pin in the I/O connector.

Note Feed external clocking signals into the PCLK pin for burst-mode handshaking and into the REQ pin when performing pattern I/O.

Deciding the Width of Data to Transfer

You can choose between a width of 8, 16, or 32 bits. Use the following table to find the valid combinations of ports and timing controllers based on the width of data you want to transfer.

Table 2-2. Port and Timing Controller Combinations

Transfer Width	Possible Port Combinations	Timing Controllers That Can Be Used
8 bits	Port 0 (DIOA<0..7>)	Group 1
	Port 2 (DIOC<0..7>)	Group 2

Table 2-2. Port and Timing Controller Combinations (Continued)

Transfer Width	Possible Port Combinations	Timing Controllers That Can Be Used
16 bits	Port 0, Port 1	Group 1
	Port 2, Port 3	Group 2
32 bits	Port 0, Port 1, Port 2, Port 3	Group 1

Deciding Transfer Direction

You can choose to send data from your NI 653*X* to the peripheral device (output) or from the peripheral device to your NI 653*X* (input).

Choosing an Internal or External REQ Source

In pattern I/O, the NI 653*X* acquires/generates data on every falling or rising edge (programmable) of the REQ signal. The REQ signal can be generated internally or based on the clock of a peripheral device. An example of using external REQ is sharing a sample clock of an analog input device so you can synchronize the analog and digital operations.

Reversing the REQ Polarity

By default, data from an external REQ source is transferred on the rising edge of the signal and on the falling edge of the internal REQ source. You can reverse the REQ polarity by using the following functions:

- NI-DAQ C interface—Specify the REQ polarity in `DIG_Group_Mode` before calling `DIG_Block_PG_Config`.
- LabVIEW—Specify the REQ polarity with the **request polarity** parameter in the Digital Mode Config VI, which is called by DIO Config VI.

Note For more information on LabVIEW VIs and NI-DAQ functions, consult the *LabVIEW Help* and the *NI-DAQ Function Reference Help*.

Refer to Table C-1, *NI 653X I/O Connector 68-Pin Assignments*, for an overview of all control/timing trigger lines.

Specifying the Transfer Rate

If you are internally generating the REQ signal, you must specify the data transfer rate. The transfer rate is specified in software by using two parameters, the timebase frequency and timebase divisor:

$$\textit{transfer rate (Hz)} = \frac{\textit{timebase frequency}}{\textit{timebase divisor}}$$

where

timebase frequency = 20 MHz, 10 MHz, 1 MHz, 100 kHz, 10 kHz, 1 kHz, or 100 Hz, and

timebase divisor = an integer between 1 and 65,355.

For example, if you specify a timebase of 100 kHz and a timebase divisor of 25, the resulting acquisition/generation rate would be 4 kHz because 100 kHz/25 = 4 kHz.

Note If you are using a version of NI-DAQ prior to version 6.8, the minimum value for timebase divisor is 2.

Note In LabVIEW, you can specify the transfer rate directly using Digital Clock Config VI (called by DIO Start VI). The software chooses the closest transfer rate by selecting the frequency and divisor. To see the actual transfer rate, create an indicator at the **actual clock frequency** output of Digital Clock Config VI.

Starting and Stopping Data Transfer—Triggering

By default, data transfer starts upon a software command (the Digital Buffer Control VI called by the DIO Start VI in LabVIEW and the `DIG_Block_In` and `DIG_Block_Out` functions in NI-DAQ C interface). However, you can use a hardware trigger to start, stop, or start and stop data transfer. Trigger signals should be connected as inputs to the ACK1 and/or ACK2 lines while in pattern I/O mode.

Note The NI 653*X* supports triggering only in pattern I/0 mode. In handshaking mode, you cannot use triggering because the handshaking lines are used to start and stop the data transfer.

Start Trigger

A start trigger is a trigger that initiates a pattern I/O upon receipt of a hardware trigger on the ACK (STARTTRIG) pin.

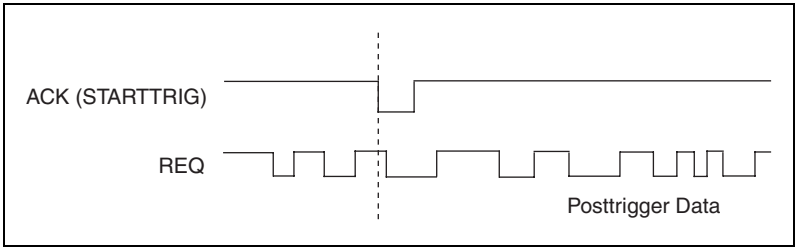


Figure 2-3. Starting Data Transfer Using a Trigger

Stop Trigger

When you use a stop trigger, data transfer starts upon a software command. Then, once a hardware trigger is received on the STOPTRIG pin, a predetermined amount of pretrigger and posttrigger data is saved in the buffer. Once this data is in the buffer, transfer stops. If the stop trigger arrives before all the pretrigger data is acquired, NI-DAQ returns an error.

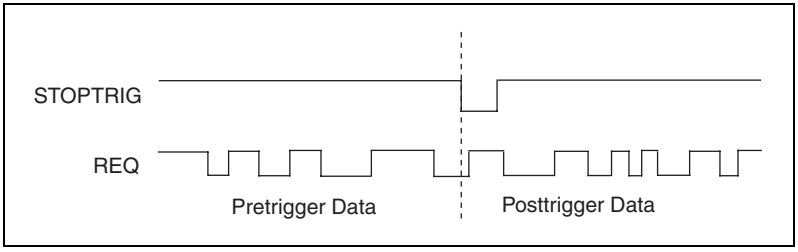


Figure 2-4. Stopping Data Transfer Using a Trigger

Start and Stop Trigger

When you use a start and stop trigger, data transfer starts upon receiving a trigger on the start trigger line (ACK/STARTTRIG pin) and ends upon receiving a trigger on the stop trigger line (STOPTRIG pin), and a predetermined amount of pretrigger and posttrigger data is saved in the buffer. If the device receives a stop trigger before a start trigger, the stop trigger is ignored. If the stop trigger arrives before all the pretrigger data is acquired, NI-DAQ returns an error.

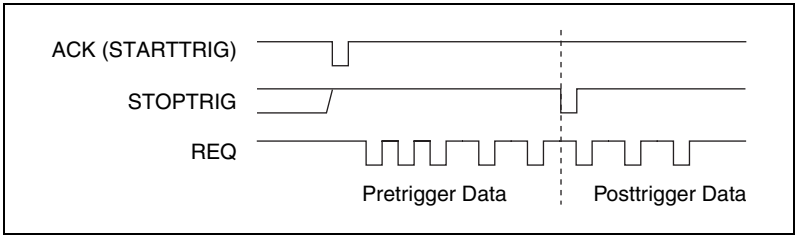


Figure 2-5. Using a Start and Stop Trigger

Pattern-Matching Trigger (Input Only)

Instead of using an external signal on the start/stop trigger pins on the I/O connector, you may start or stop (not both) an operation once a user-specified digital pattern is matched or not matched.

Specify four parameters to set up a pattern-matching trigger:

- Whether it is a start or stop trigger
- The data pattern to be detected/matched
- The mask, which selects the bits of interest for pattern comparison (0 for bits not of interest)
- The polarity (whether to trigger on data that matches or mismatches the specified pattern)

For example, if you want to start acquisition when the two least significant bits of your data are 1 and 0, you would specify your trigger parameters to match those in Figure 2-6.

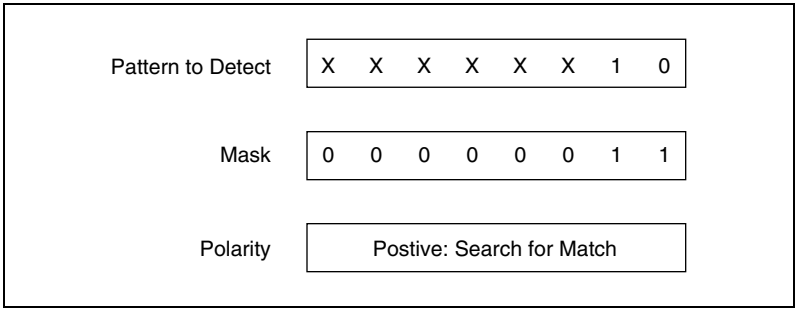


Figure 2-6. Pattern-Matching Trigger Example

Tip To prevent a transient data value during line switching from falsely causing a match, set a valid pattern for at least 60 ns to guarantee detection. In addition, keep glitches to less than 20 ns to guarantee rejection.

Choosing Continuous or Finite Data Transfer

You can transfer data continuously into or from computer memory or specify the number of points you want to transfer.

Finite Transfers

For finite transfers, the NI 653*X* transfers the specified amount of data to/from computer memory and stops the operation.

Continuous Input

For continuous input, the NI 653*X* transfers input data to the computer memory buffer continuously. As the device fills the buffer, call the `DIG_DB_Transfer` function or the DIO Read VI to retrieve the data. If at any time the device runs out of space in the buffer, it stops the operation and NI-DAQ returns an error.

You can allow the device to continue acquiring when it runs out of buffer space and overwrite data you have not yet read. You can specify this through the `oldDataStop` parameter in the `DIG_DB_Config` function and the **data overwrite/regen.** parameter in the Digital Buffer Control VI, which is called by the DIO Start VI.

Continuous Output

Similarly, with continuous output, the NI 653*X* continuously reads data from computer memory. As the device retrieves data from the buffer, call the `DIG_DB_Transfer` function or the DIO Write VI to write the data. The device stops and returns an error if it runs out of data to generate, but you can allow it to regenerate data that has already been generated. As in continuous input, you configure the device to allow regeneration with the `oldDataStop` parameter in the `DIG_DB_Config` function and the **data overwrite/regen.** parameter in the Digital Buffer Control VI, which is called by the DIO Start VI.

- NI 6534

  With the NI 6534, if you want to repeatedly generate the same block of data, you can load a buffer of data into onboard memory and continuously loop through this data block. With this option, data is only transferred from computer memory to the device onboard memory once, and the device continuously generates the same block of data from its onboard memory. This allows the device to output data at higher rates because it is not limited by the PCI bus bandwidth. To enable onboard memory looping:

  - NI-DAQ C interface—In `Set_DAQ_Device_Info`, set `ND_PATTERN_GENERATION_LOOP_ENABLE` to `ND_ON`.
  - LabVIEW—Use the DIO Parameter VI to set the Pattern Generation Loop attribute to ON.

  You have the following restrictions when looping from the onboard memory of the NI 6534:

  - For 8-bit data, the buffer size must be a multiple of 4.
  - For 16-bit data, the buffer size must be an even number.

  There are no restrictions for 32-bit data. For 8- or 16-bit data, you may need to add dummy data to the buffer to make it the correct size.

Choosing DMA or Interrupt Transfers

When using DMA (default), the NI 6534 transfers data in 32-byte blocks, and the NI 6533 transfers data in 4-byte blocks. Therefore, at any time during a continuous operation, there may be up to 31 bytes (or 3 bytes for the NI 6533) of data in an internal FIFO. You can use interrupt-driven transfers if you need to retrieve data immediately as it is acquired. Interrupt-driven transfers are slower and take more processing time from the computer than DMA-driven transfers.

Monitoring Data Transfer

To monitor your data transfer once data transfer starts:

- NI-DAQ C interface—Call `DIG_Block_Check` to monitor finite data transfer. For continuous transfers, use `Get_DAQ_Device_Info` to obtain the cumulative transfer count (`DIG_Block_Check` does not return the number of buffer iterations completed). The following table lists the attribute types and values returned for `Get_DAQ_Device_Info`:

Transfer Direction	Attribute	Value Returned
Input	ND_READ_MARK_H_SNAPSHOT_GR1	Most significant 32 bits of transfer count
	ND_READ_MARK_H_SNAPSHOT_GR2	
	ND_READ_MARK_L_SNAPSHOT_GR1	Least significant 32 bits of transfer count
	ND_READ_MARK_L_SNAPSHOT_GR2	
Output	ND_WRITE_MARK_H_SNAPSHOT_GR1	Most significant 32 bits of transfer count
	ND_WRITE_MARK_H_SNAPSHOT_GR2	
	ND_WRITE_MARK_L_SNAPSHOT_GR1	Least significant 32 bits of transfer count
	ND_WRITE_MARK_L_SNAPSHOT_GR2	

Note You should always read the least significant bits of the transfer count before reading the most significant bits. The 32 most significant bits of the transfer count is cached in software when you read the least significant bits.

- LabVIEW—Use the Digital Buffer Write VI or the Digital Buffer Read VI, which are called by the DIO Read VI, the DIO Write VI, and the DIO Wait VI.

Connecting Signals

Connect digital input signals to the I/O connector using the pinout diagrams, Figure C-1, *NI 653X I/O Connector 68-Pin Assignments*, or Figure C-2, *68-to-50-Pin Adapter Pin Assignments*.

If you are using an external source for your REQ signal, connect it to the appropriate REQ pin of the I/O connector.

If you are using external start and/or stop triggers, connect to the appropriate pins—start trigger (ACK/STARTTRIG) and/or stop trigger (STOPTRIG).

Creating a Program

Using the following flowcharts as a guide, create a program to perform pattern I/O. Figures 2-7 and 2-8 display flowcharts for C programming using NI-DAQ, while Figure 2-9 shows a LabVIEW programming flowchart.

The boxes represent function names for the appropriate software, and the diamonds represent decision points.

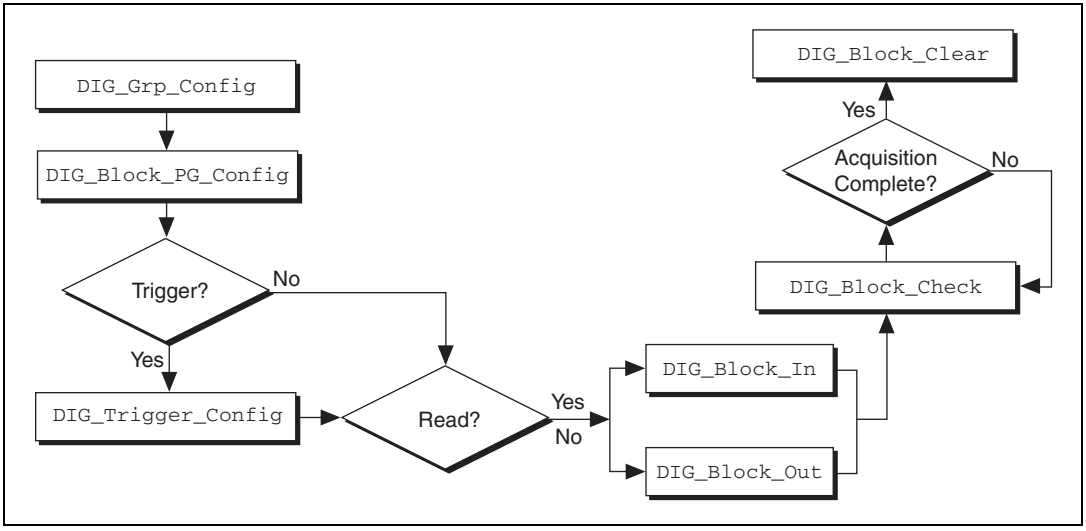


Figure 2-7. Programming Pattern I/O (Single Buffer) in NI-DAQ C API

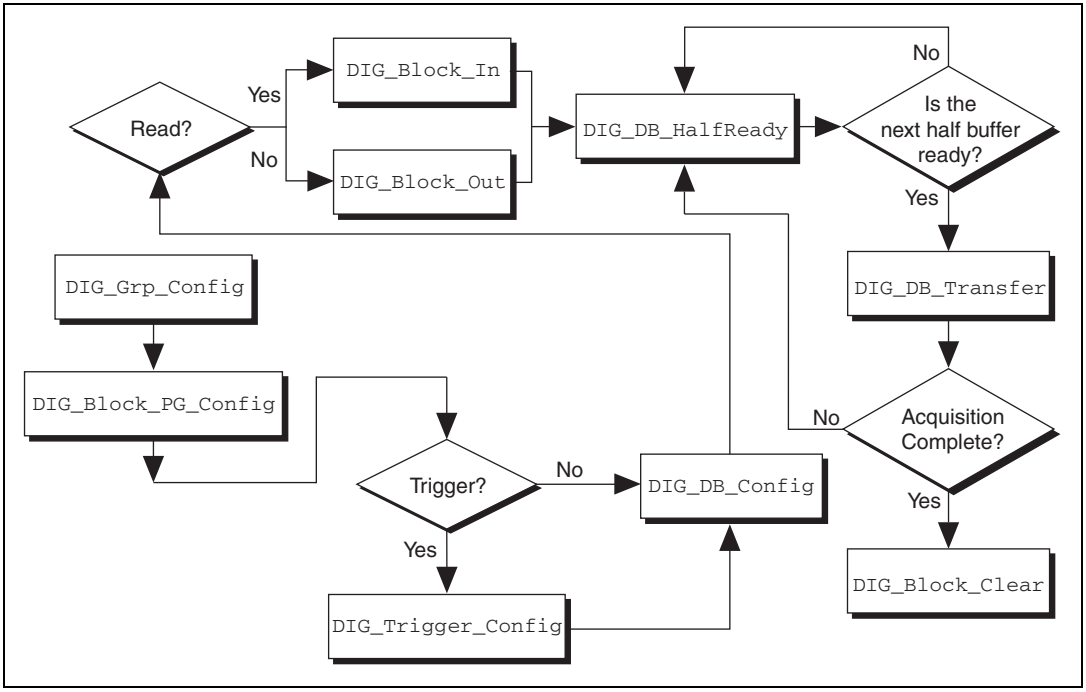


Figure 2-8. Programming Pattern I/O (Continuous) in NI-DAQ C API

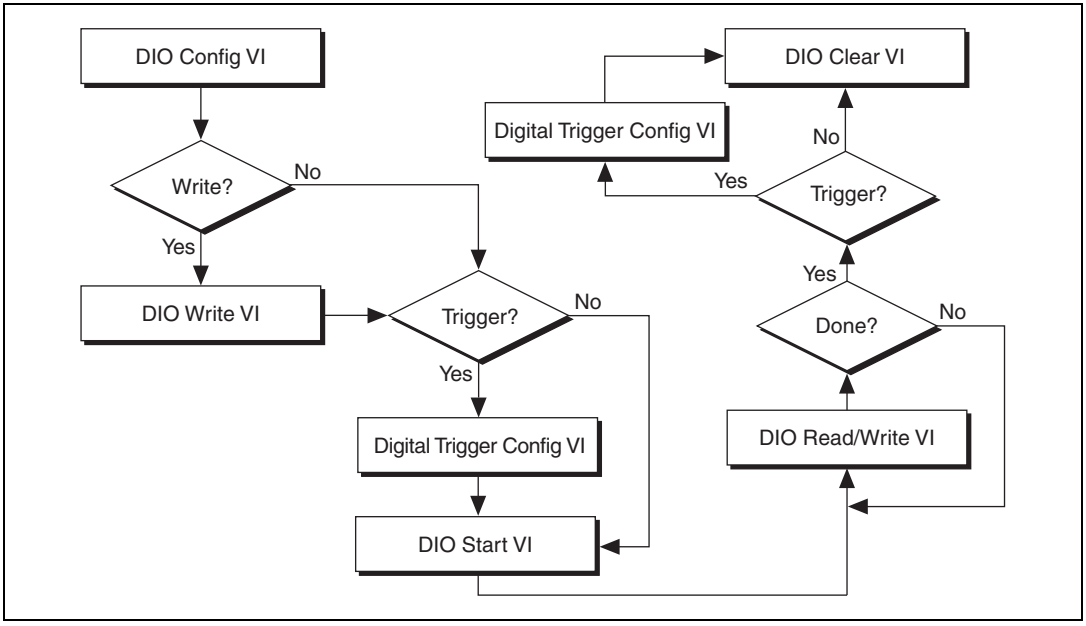


Figure 2-9. Programming Pattern I/O in NI-DAQ LabVIEW/LabVIEW RT API

Notes If you are using an external clock for finite pattern input, the NI 653*X* requires an extra clock edge to move data from the DIO ASIC and into the computer memory after the final data sample is acquired.

If you are performing a finite pattern output operation, you can call DIO Wait VI instead of the DIO Write VI after the DIO Start VI. For more information about these VIs, refer to the *LabVIEW Help*.

- NI PCI/PXI-6534

  For output buffered transfers the NI 6534 by default preloads the onboard memory with data before starting the output operation. Preloading eliminates or reduces the impact of the PCI bus bandwidth limitations and increases the overall transfer rate. The preloading process causes a small delay between the start command in software and the actual start of data transfer. If this is a concern, you can disable the preloading by calling the following function/VI before the software start command:

  - NI-DAQ C interface—In the `Set_DAQ_Device_Info` function, set the `ND_FIFO_TRANSFER_COUNT` to `ND_NONE`.
  - LabVIEW—Use the DIO Parameter VI to set the **Scarabs Preload Enable** attribute to **None**.

Note Because output data is preloaded to the NI 6534 buffer, you cannot use DAQEvents (called Progress events in the CWDO object of Measurement Studio) to monitor the progress of pattern generation. A DAQEvent is fired when data is preloaded into the NI 6534 onboard memory from the PC memory, so the event indicates a data transfer from the PC memory, *not* the progress of pattern generation from the NI 6534 to an external device.

Transferring Data Between Two Devices—Handshaking I/O

If you want to communicate with an external device using an exchange of signals to request and acknowledge each data transfer, use the handshaking I/O mode.

Choosing the Width of Data to Transfer

You can choose between a width of 8, 16, or 32 bits. Use the following table to find the valid combinations of ports and timing controllers you can use based on the width of data you want to transfer.

Table 2-3. Port and Timing Controller Combinations

Transfer Width	Possible Port Combinations	Timing Controllers That Can Be Used
8 bits	Port 0 (DIOA<0..7>)	Group 1
	Port 2 (DIOC<0..7>)	Group 2
16 bits	Port 0, Port 1	Group 1
	Port 2, Port 3	Group 2
32 bits	Port 0, Port 1, Port 2, Port 3	Group 1

Deciding Data Transfer Direction

You can choose to send data from the NI 653*X* to the peripheral device (output) or from the peripheral device to the NI 653*X* (input).

Deciding Which Handshaking Protocol to Use

The NI 653*X* supports several different handshaking protocols to communicate with your peripheral device. The protocol you select determines the timing of the ACK and REQ signals.

From the perspective of the NI 653*X*, the peripheral device requests the transfer of data by signaling on the REQ line. The NI 653*X* acknowledges it is ready to transfer data by signaling on the ACK line.

Use Table 3-1, *Handshaking Protocol Characteristics*, to select a handshaking protocol for your application. To select a protocol compatible with your peripheral device, compare the handshaking sequence and state machine diagrams for each protocol in the later sections of Chapter 3, *Timing Diagrams*.

Using the Burst Protocol

The burst protocol differs from all the other handshaking protocols in that it is the only synchronous (clocked) protocol. In addition to ACK and REQ, the NI 653*X* and peripheral device share a clock signal over the PCLK line. Refer to Chapter 3, *Timing Diagrams*, for more information about the burst protocol.

If you want to acquire or generate patterns of every edge of a clock signal, refer to the *Generating and Receiving Digital Patterns and Waveforms—Pattern I/O* section.

Note Feed external clocking signals into the PCLK pin for burst-mode handshaking and into the REQ pin when performing pattern I/O.

Deciding the PCLK Signal Direction

The NI 653*X* can receive an external PCLK signal to control data transfers or generate a PCLK signal using an internal 32-bit counter to output to the peripheral device. By default, the NI 653*X* generates the PCLK signal for input operations and receives an external PCLK signal for output operations.

To set the direction of the PCLK signal:

- NI-DAQ C interface—Set the `ND_CLOCK_REVERSE_MODE` to `ND_ON` in `Set_DAQ_Device_Info`.
- LabVIEW—Set the **Clock Reverse Mode** attribute to **ON** using the DIO Parameter VI.

Note For more information on LabVIEW VIs and NI-DAQ functions, consult the *LabVIEW Help* and the *NI-DAQ Function Reference Help*.

Selecting ACK/REQ Signal Polarity

For all handshaking protocols except 8255 emulation, you can set the polarity of the ACK and REQ signals to active high or active low through software. By default, these signals are active high in NI-DAQ functions and active low in LabVIEW VIs. Refer to Table C-1, *NI 653X I/O Connector 68-Pin Assignments*, for an overview of all control/timing trigger lines.

Choosing Whether to Use a Programmable Delay

For all the protocols, you can set a programmable delay. A programmable delay is useful when the handshaking signals of the NI 653*X* occur faster than the peripheral device can handle.

For all protocols except burst, the delay increases the time before the NI 653*X* can respond to the REQ signal. For the burst protocol, the programmable delay selects the frequency of the clock signal when you use an internally generated clock source. You can change the PCLK frequency by modifying the ACK Modify Amount parameter of the Digital Mode Config VI or the ACK Delay Time attribute of the `DIG_Grp_Mode` function in NI-DAQ C interface. Use the following table to find the resulting period in nanoseconds. The PCLK frequency is then selected by NI-DAQ based on this choice.

PCLK Period in ns	PCLK Frequency in MHz
50	20
100	10
200	5
300	3.33
400	2.5
500	2
600	1.66
700	1.43

The state machine diagrams in Chapter 3, *Timing Diagrams*, show more precisely where this delay occurs in the handshaking sequence.

Choosing Continuous or Finite Data Transfer

You can transfer data indefinitely to/from computer memory or finitely by specifying the number of points you want to transfer.

Finite Transfers

For finite transfers, the NI 653*X* transfers the specified amount of data to/from a computer memory buffer and stops the operation.

Continuous Input

For continuous input, the NI 653*X* transfers input data to the computer memory buffer continuously. As the device fills the buffer, call the `DIG_DB_Transfer` function or the DIO Read VI to retrieve the data. If at any time the device runs out of space in the buffer, it pauses the handshaking operation until your program clears more buffer space.

You can allow the device to continue acquiring data when it runs out of buffer space and overwrite data you have not yet read. You can specify this through the `oldDataStop` parameter in the `DIG_DB_Config` function and the **data overwrite/regen.** parameter in the Digital Buffer Control VI called by the DIO Start VI.

Continuous Output

Similarly, with continuous output, the NI 653*X* continuously reads data from computer memory. As the device retrieves data from the buffer, call the `DIG_DB_Transfer` function or the DIO Write VI to write new data to the buffer. The device pauses the handshaking operation if it runs out of data to generate. The data transfer resumes once more data is available.

You have the option to allow it to regenerate data that has already been output. As in continuous input, you specify the device to allow regeneration though the `oldDataStop` parameter in the `DIG_DB_Config` function and the **data overwrite/regen.** parameter in the Digital Buffer Control VI, called by the DIO Start VI.

- NI 6534

With the NI 6534, if you want to repeatedly generate the same block of data, you can load a buffer of data into onboard memory and continuously loop through this data block. With this option, data is only transferred from computer memory to the NI 6534 onboard memory once, and the device generates the same block of data continuously from its onboard memory,

allowing the device to generate data at higher rates because it is not limited by the PCI bus bandwidth. To enable onboard memory looping:

- NI-DAQ C interface—In `Set_DAQ_Device_Info`, set `ND_PATTERN_GENERATION_LOOP_ENABLE` to `ND_ON` in the `Set_DAQ_Device_Info` function.
- LabVIEW—Use the DIO Parameter VI to set the Pattern Generation Loop Enable attribute to **ON**.

You have the following restrictions when looping from the onboard memory of the NI 6534:

- For 8-bit data, the buffer size must be a multiple of 4.
- For 16-bit data, the buffer size must be an even number.

There are no restrictions for 32-bit data. For 8- or 16-bit data, you may need to add dummy data to the buffer to make it the correct size.

Choosing DMA or Interrupt Transfers

When using DMA (default), the NI 6534 transfers data in 32-byte blocks, and the NI 6533 transfers data in 4-byte blocks. Therefore, at any time during a continuous operation, there may be up to 31 bytes (or 3 bytes for the NI 6533) of data in an internal FIFO. You can use interrupt-driven transfers if you need to retrieve data as soon as it is acquired. Interrupt-driven transfers are slower and take more processing time from the computer than DMA-driven transfers.

Connecting Signals

1. Connect the digital input signals to the I/O connector using the pinout diagrams, Figure C-1, *NI 653X I/O Connector 68-Pin Assignments*, and Figure C-2, *68-to-50-Pin Adapter Pin Assignments*.
2. Connect the ACK pin of the NI 653*X* to the NI 653*X*-ready line of the peripheral device.
3. Connect the REQ pin of the NI 653*X* to the peripheral-ready line of the peripheral device.

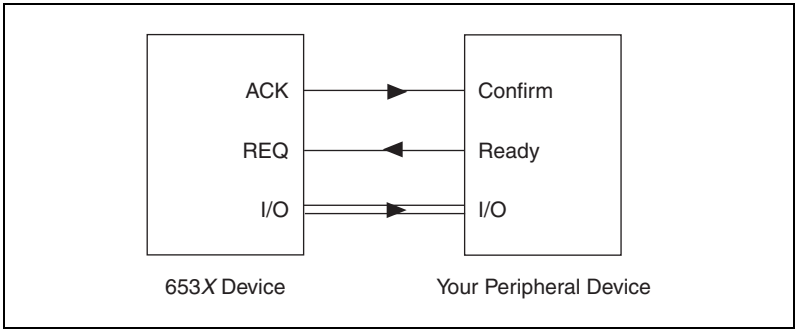


Figure 2-10. Connecting Signals

If you are using the burst protocol, make the connection to the appropriate PCLK pin on the NI 653*X*.

Choosing the Startup Sequence

To avoid invalid or missing data when the ACK and REQ lines change polarity to either active high or active low, start a transfer using one of the following methods:

- Control the configuration and use an initialization order.
- Select compatible line polarities and default line levels.

Using an Initialization Order

This startup sequence ensures the NI 653*X* is configured and is driving a valid ACK value before you enable the transfer on the peripheral device. Similarly, you can make sure the peripheral device is configured and is driving a valid REQ value before you enable the transfer on the NI 653*X*.

1. Configure the NI 653*X* for a mode compatible with your peripheral device.
2. Configure and reset the peripheral device, if appropriate.
3. Enable the input device (NI 653*X* or peripheral device) and begin a transfer.
4. Enable the output device (NI 653*X* or peripheral device) and begin a transfer.

To control this initialization order, you must enable and disable the peripheral device and control the order in which the NI 653*X* and the peripheral device are enabled. You can use the extra input and output lines for this purpose.

Controlling the startup sequence does not apply to buffered (block) operations. In a buffered operation, the NI-DAQ C interface configures and enables the NI 653*X* at the same time, when you start the actual data transfer. For buffered operations, control the line polarities as a start-up method.

Controlling Line Polarities

If you cannot control the initialization order of the NI 653*X* and peripheral device, you can ensure an optimum startup if you select the polarities of the ACK and REQ lines so that the power-up, undriven states of the control lines are the inactive states.

By default, the power-up, undriven control-line state of the REQ and ACK lines is low. If you want to change state to high, use one of the three following methods:

- Use the CPULL bias-selection line and connect the CPULL pin on the I/O connector to the +5 V pin. This provides 2.2 kΩ pull-up resistors on all control lines.
- Choose a mode with active-high REQ and ACK signals.
- Use your own pull-up resistors.

For information about using the CPULL line to control the pull-up and pull-down resistors, refer to the *Power-On State* section of Appendix D, *Hardware Considerations*.

Creating a Program

Using the following flowcharts as a guide, create a program to perform handshaking I/O. Figures 2-11 and 2-12 display flowcharts for C programming using NI-DAQ, and Figures 2-13 and 2-14 show LabVIEW programming flowcharts.

The boxes represent function names for the appropriate software, and the diamonds represent decision points.

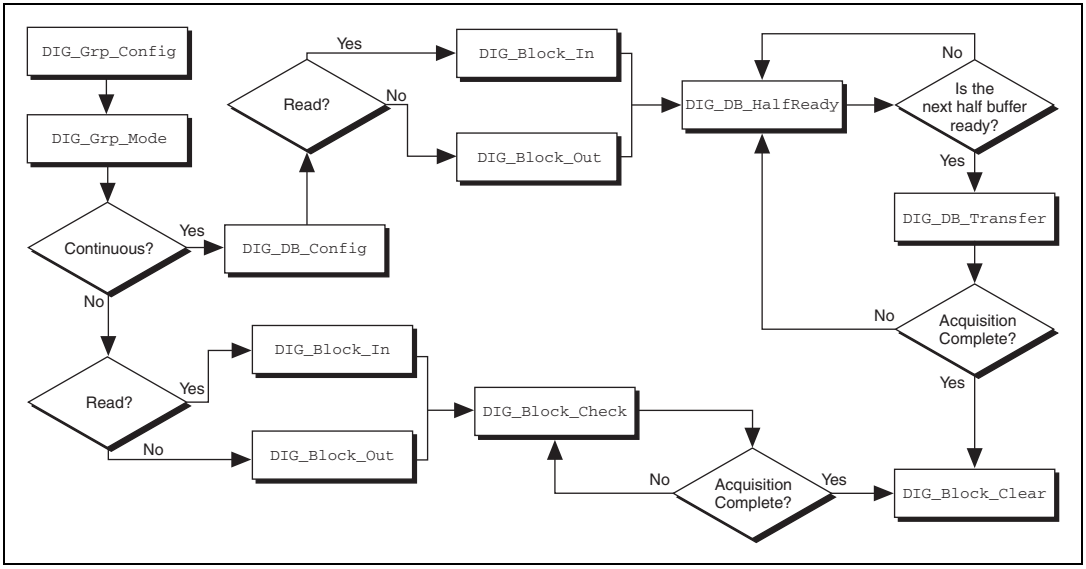


Figure 2-11. Programming Buffered Handshaking I/O in NI-DAQ C API

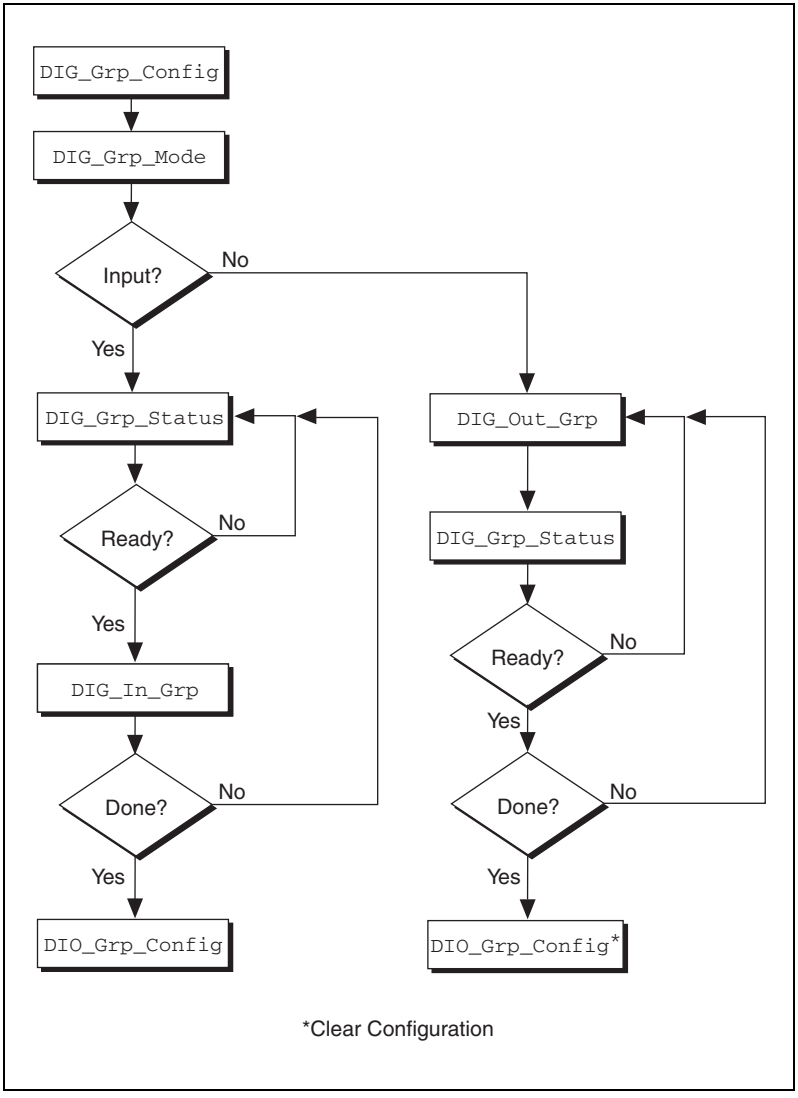


Figure 2-12. Programming Unbuffered Handshaking I/O in NI-DAQ C API

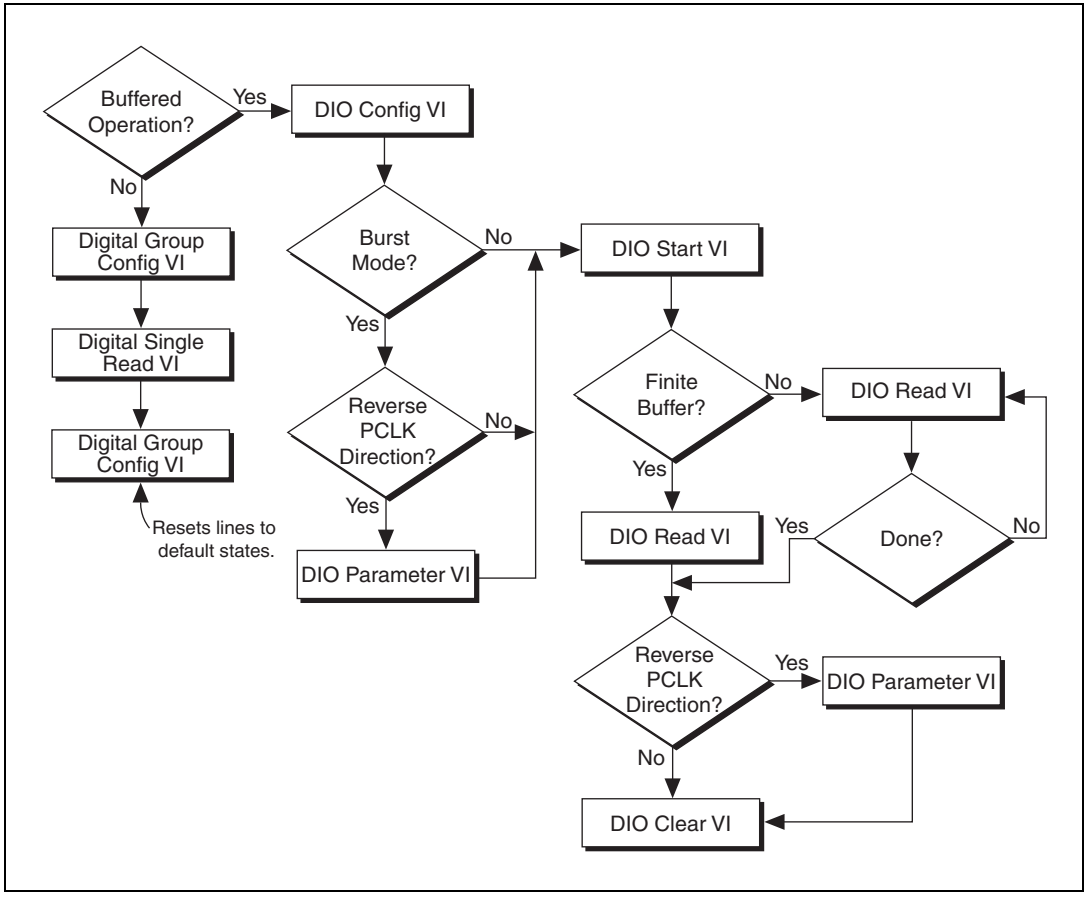


Figure 2-13. Programming Handshaking Input in NI-DAQ LabVIEW/LabVIEW RT API

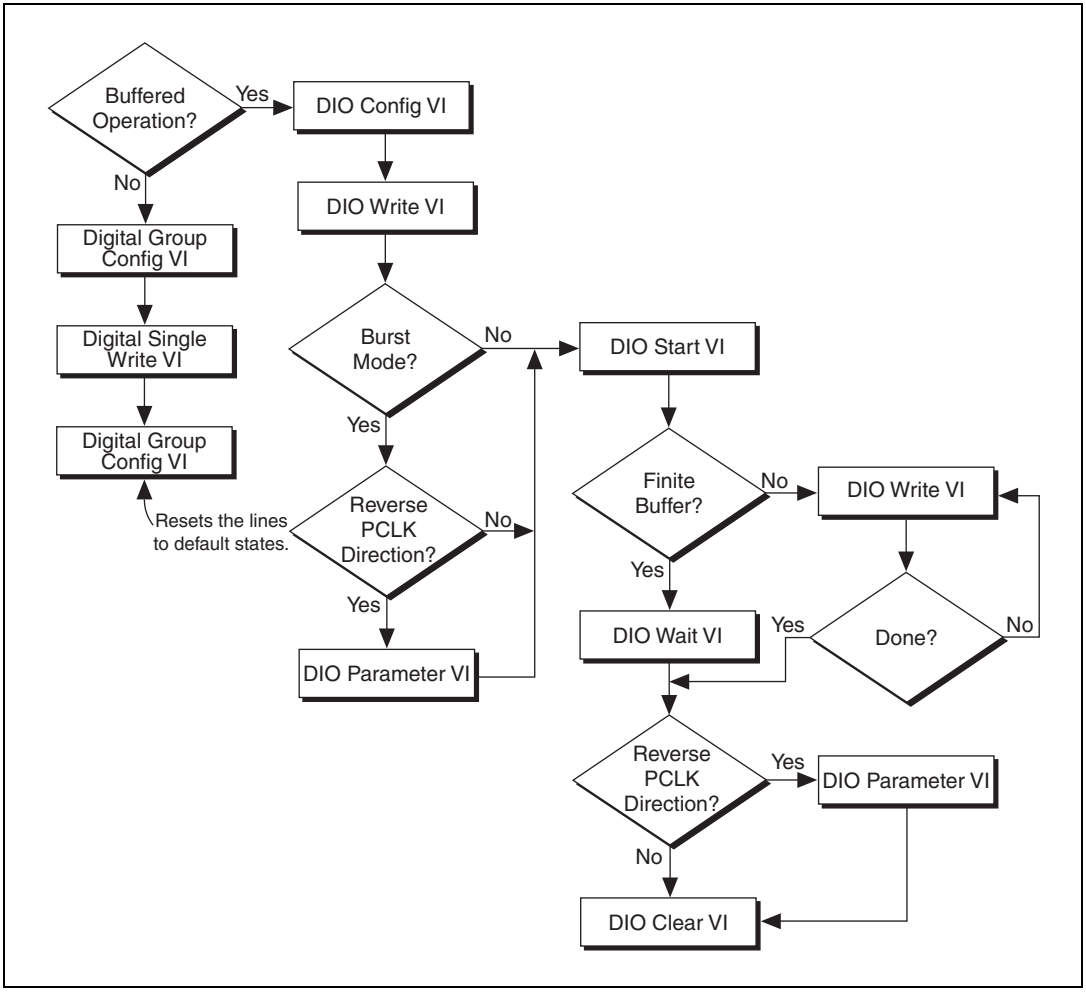


Figure 2-14. Programming Handshaking Output in NI-DAQ LabVIEW/LabVIEW RT API

- NI 6534

  By default, for output buffered transfers the NI 6534 preloads the onboard memory with data before starting the output operation. Preloading the memory eliminates or reduces the impact of the PCI bus bandwidth limitations and increases the overall transfer rate.

The preloading process causes a small delay between the start command in software and the actual start of data transfer. If this delay is a concern, you may disable the preloading by calling the following function/VI before the software start command:

- NI-DAQ C interface—In the `Set_DAQ_Device_Info` function, set the ND_FIFO_Transfer_COUNT to ND_NONE.
- LabVIEW—In the DIO Parameter VI, set the Scarabs Preload Enable attribute to None.

Note Because output data is preloaded to the NI 6534 buffer, you cannot use DAQ events (called progress events in the CWDO object of Measurement Studio) to monitor the progress of a handshaking output operation. A DAQEvent is fired when data is preloaded into the NI 6534 onboard memory from the PC memory, so the event indicates a data transfer from the PC memory, not the progress of data output from the NI 6534 to an external device.

Monitoring Line State—Change Detection

You can configure your NI 653*X* to acquire data whenever the state of one or more data lines change. Once the NI 653*X* detects a change in one of the selected lines, it captures data within 50–150 ns and outputs a pulse on the REQ pin. This mode increases CPU and bus efficiency because you can monitor activity on input lines without continuously polling or transferring unnecessary data during periods of inactivity.

Tip When you use the NI 653*X* alone, it detects whether a change occurred, but when you use the NI 653*X* and an NI 660*X* counter/timer device (using a RTSI line), the relative time between changes can be acquired by the NI 660*X*.

Deciding the Width of Data to Acquire

You can choose between a width of 8, 16, or 32 bits. Use the following table to find the valid combinations of ports and timing controllers you can use based on the width of data you want to acquire.

Table 2-4. Port and Timing Controller Combinations

Transfer Width	Possible Port Combinations	Timing Controllers That Can Be Used
8 bits	Port 0 (DIOA<0..7>)	Group 1
	Port 2 (DIOC<0..7>)	Group 2

Table 2-4. Port and Timing Controller Combinations (Continued)

Transfer Width	Possible Port Combinations	Timing Controllers That Can Be Used
16 bits	Port 0, Port 1	Group 1
	Port 2, Port 3	Group 2
32 bits	Port 0, Port 1, Port 2, Port 3	Group 1

Deciding Which Lines You Want to Monitor

You need to specify which of the lines in your acquisition you want to monitor for changes.

Specify which bits are significant to you by using a software line mask in the `DIG_Trigger_Config` function in NI-DAQ C interface, and the Digital Trigger Config VI for LabVIEW. In the following example, the user specifies the mask to detect changes on the two least-significant bits of a port. Pattern 1 does not have changes in the two bits of interest, and data is not latched. For pattern 2, however, a change is detected on one of the two bits of interest, and the value of the entire port is acquired.

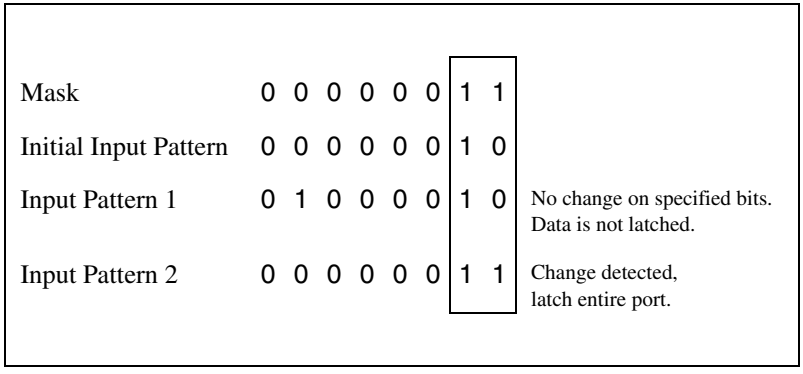


Figure 2-15. Change Detection Example Settings

Deciding How to Start and Stop Data Transfer—Triggering

By default, data transfer starts upon a software command (the Digital Buffer Control VI called by the DIO Start VI in LabVIEW and the `DIG_Block_In` and `DIG_Block_Out` functions in NI-DAQ C interface). However, you can use a hardware trigger to start, stop, or start and stop data transfer.

The three types of trigger signals available are the start trigger, the stop trigger, or the start and stop trigger.

Start Trigger

A start trigger is a trigger that initiates a pattern I/O upon receipt of a hardware trigger on the ACK (STARTTRIG) pin.

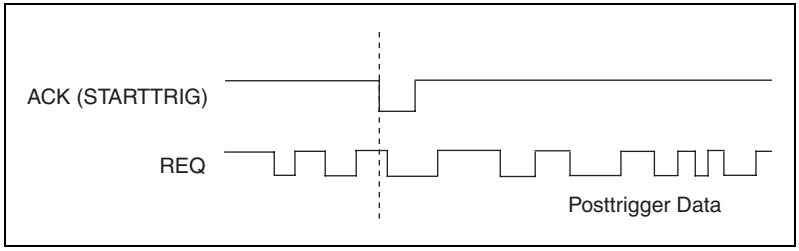


Figure 2-16. Starting Data Transfer Using a Trigger

Stop Trigger

When using a stop trigger, transfer starts upon a software command. Once a hardware trigger is received on the STOPTRIG pin, a predetermined amount of pretrigger and posttrigger data is saved in the buffer. Once this data is in the buffer, transfer stops. If the stop trigger arrives before all the pretrigger data is acquired, an error is returned in software.

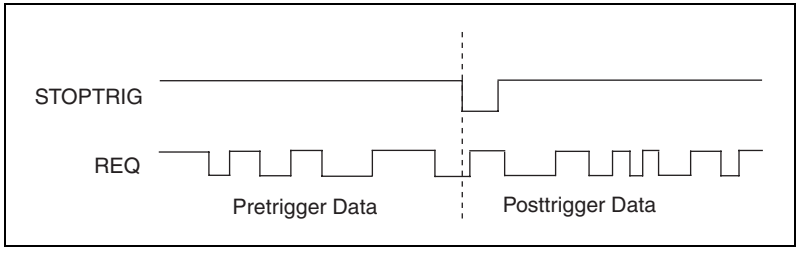


Figure 2-17. Stopping Data Transfer Using a Trigger

Start and Stop Trigger

When using a start and stop trigger, transfer starts upon receiving a trigger on the start trigger line (ACK/STARTTRIG pin) and ends upon receiving a trigger on the stop trigger line (STOPTRIG pin). A predetermined amount of pretrigger and posttrigger data is saved in the buffer. If a stop trigger is received before a start trigger, it is ignored. If the stop trigger arrives before all the pretrigger data is acquired, NI-DAQ returns an error.

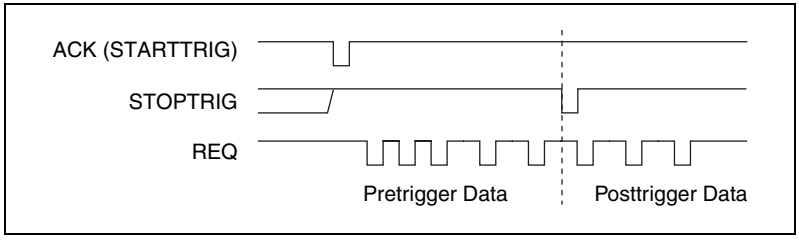


Figure 2-18. Using a Start and Stop Trigger

Pattern-Matching Trigger

Instead of using an external signal on the start/stop trigger pins on the I/O connector, you may start or stop (not both) an operation once a user-specified digital pattern is matched.

Specify four parameters to set a pattern-matching trigger:

- Whether it is a start or stop trigger
- The data pattern to be detected/matched
- The mask, which selects the bits of interest for pattern detection

Note The mask for the pattern-matching trigger is the same as the one used for change detection. In other words, input lines significant for the pattern-matching trigger are also significant for change detection.

- Polarity (whether to detect data that matches or mismatches the specified pattern)

The NI 653*X* immediately detects any occurrence of a specific pattern as the data arrives. When a match occurs, the NI 653*X* starts acquiring data. For example, if you want to start an acquisition when the two least significant bits of your data are 1 and 0, you would specify your trigger parameters to match those in Figure 2-19.

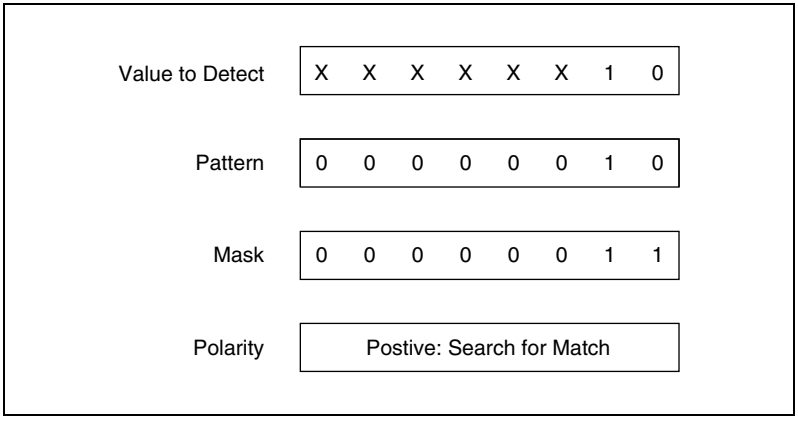


Figure 2-19. Pattern-Detection Trigger Example

Tip To prevent a transient data value during line switching from falsely causing a match, set a valid pattern for at least 60 ns to guarantee detection. In addition, keep glitches to less than 20 ns to guarantee rejection.

Choosing Continuous or Finite Data Transfer

You can continuously acquire data into or transfer data from computer memory or specify the number of points you want to transfer.

Finite Transfers

For finite transfers, the NI 653*X* acquires the specified amount of data to a computer memory buffer and stops the operation.

Continuous Input

For continuous input, the NI 653*X* continuously transfers input data to the computer memory buffer. As the device fills the buffer, call the `DIG_DB_Transfer` function or the DIO Read VI to retrieve the data. If at any time the device runs out of space in the buffer, it stops the operation and NI-DAQ returns an error.

You can allow the device to continue when it runs out of buffer space and overwrite data you have not yet read. You can specify this though the `oldDataStop` parameter in the `DIG_DB_Config` function and the **data overwrite/regen.** parameter in the Digital Buffer Control VI, called by the DIO Start VI.

Choosing DMA or Interrupt Transfers

When using DMA (default), the NI 6534 transfers data in 32-byte blocks, and the NI 6533 transfers data in 4 byte blocks. Therefore, at any time during a continuous operation, there may be up to 31 bytes (or 3 bytes for the NI 6533) of data in an internal FIFO. You can use interrupt-driven transfers if you need to retrieve data immediately as it is acquired. Interrupt-driven transfers are slower and take more processing time from the computer than DMA-driven transfers.

Connecting Signals

Connect digital input signals to the I/O connector using the pinout diagrams, Figure C-1, *NI 653X I/O Connector 68-Pin Assignments*, or Figure C-2, *68-to-50-Pin Adapter Pin Assignments*.

If you are using external start and/or stop triggers, connect to the appropriate pins—start trigger (ACK or STARTTRIG) and/or stop trigger (STOPTRIG).

Creating a Program

Using the following flowcharts as a guide, create a program to perform change detection. Figure 2-20 and Figure 2-21 display flowcharts for C programming using NI-DAQ, and Figure 2-22 shows a LabVIEW programming flowchart.

The boxes represent function names for the appropriate software, and the diamonds represent decision points.

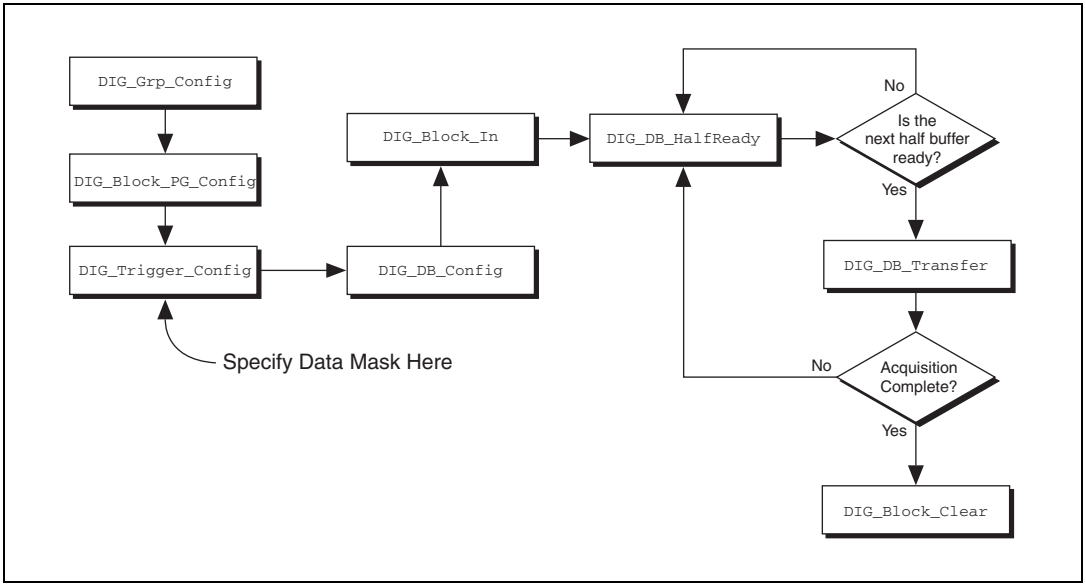


Figure 2-20. Programming Change Detection (Continuous) in NI-DAQ C API

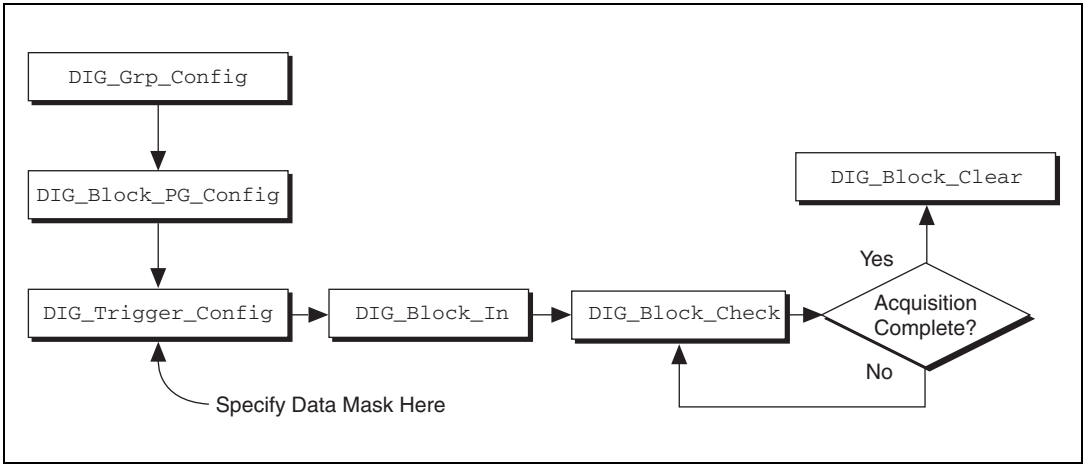


Figure 2-21. Programming Change Detection (Single Buffer) in NI-DAQ C API

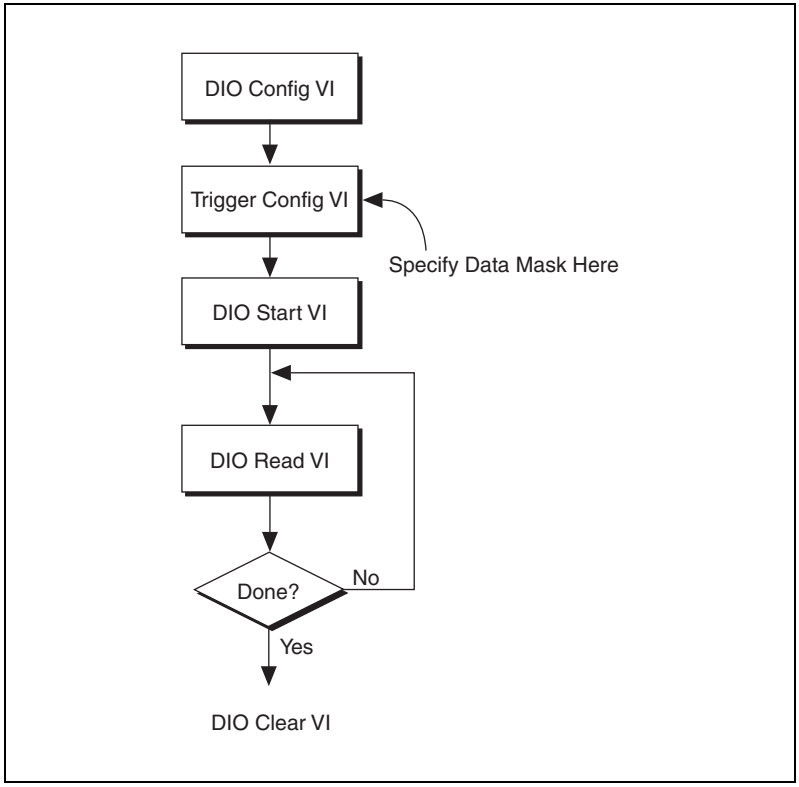


Figure 2-22. Programming Change Detection for NI-DAQ LabVIEW/LabVIEW RT API

3

Timing Diagrams

This chapter contains timing diagrams for the handshaking and pattern I/O modes. You can use these diagrams to learn details about what happens in hardware when you use these modes.

Note All timing diagrams are in nanoseconds.

Pattern I/O Timing Diagrams

Use pattern I/O to transfer data at a timed interval upon the rising or falling edge of the REQ signal. The REQ signal can be internally generated by the NI 653*X* or externally supplied through the I/O connector.

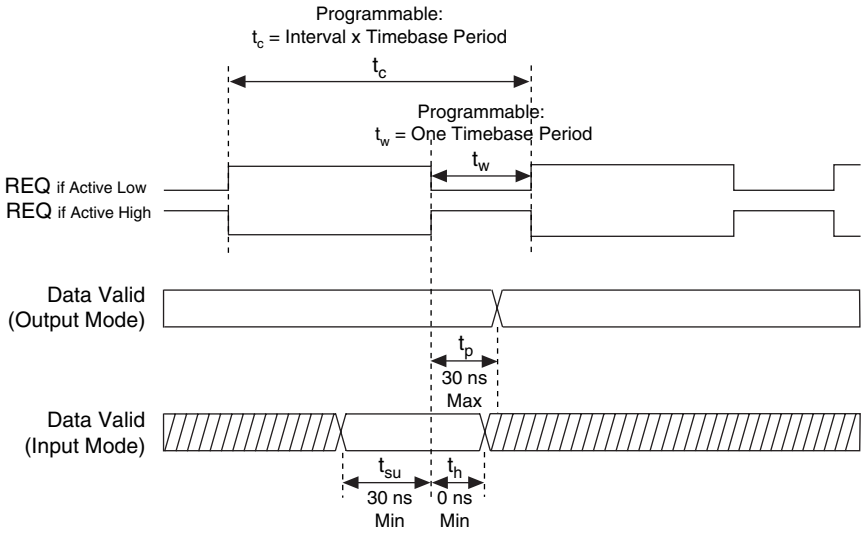
Note Your transfer rate is limited by the *minimum* available bus bandwidth in your computer system, unless you are using the NI PCI/PXI-6534, which has onboard memory. Otherwise, you are limited by the number of other devices using the bus and your application software, both of which can lower your transfer rate. For more information about transfer rates, refer to Appendix E, *Optimizing Your Transfer Rates*.

Internal REQ Signal Source

The NI 653*X* can internally generate a signal (REQ) with which to strobe data. To program the frequency of this signal, specify the timebase and interval as shown in the *Specifying the Transfer Rate* section of Chapter 2, *Using Your NI 653X*. The device captures data on the rising (active low) or falling edge (active high) of this signal. You can select the polarity of the REQ signal through software, as described in the *Reversing the REQ Polarity* section of Chapter 2, *Using Your NI 653X*.

When generating an internal REQ signal, the asserted time of the resulting clock is one period of the timebase used to generate the REQ signal. The exception is if you use a 20 MHz timebase (50 ns) and select an interval of 1. The REQ pulse is then asserted for 20–30 ns.

Note If you are using a version of NI-DAQ earlier than version 6.8, the minimum value for the interval parameter is 2.



Parameter	Description
t_c*	Cycle time
t_w*	Width of pulse
t_p	Propagation time to valid output data
t_{su}	Setup time
t_h	Hold time

* The NI 6534 transfers data at 20 MHz when the cycle time (t_c) for REQ pulse is 50 ns and width of the REQ pulse (t_w) is 20–30 ns.

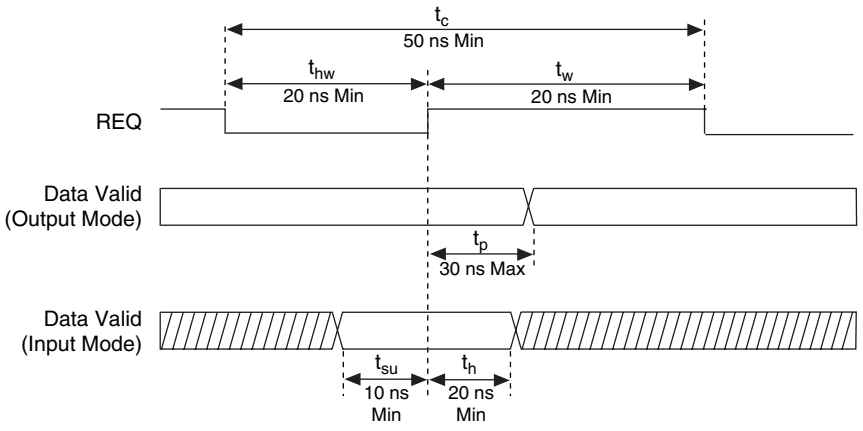
Figure 3-1. Internal Request Timing Diagram

External REQ Signal Source

Use an external request when you want to time data transfers using an external signal on the REQ pin of the I/O connector. You can select the polarity of the REQ signal. If you choose active high (default), the NI 653*X* latches the data on the I/O pins on the *rising* edge of the REQ signal. If you choose active low, the NI 653*X* latches the data on the I/O pins on the *falling* edge of the REQ signal. The low time and high time of the REQ signal must each be >20 ns. The minimum duration for a period of the REQ signal is 50 ns.

Note For data transfers that use a hardware start trigger, there is no mandatory setup (t_{su}) or hold time (t_h) for the STARTTRIG (ACK) signal. It can be asserted at any point before, during, or after the REQ edge. If STARTTRIG is asserted too close to the REQ edge, it may not be recognized until the next REQ edge. To avoid this uncertainty, you can observe an optional setup time of 15 ns; in other words, assert STARTTRIG at least 15 ns before the start of the REQ pulse.

The STARTTRIG signal is synchronized to the REQ edge using a flip-flop. Because of this synchronization flip-flop, there is a one REQ-pulse delay after STARTTRIG before the data capture begins. A two-cycle delay is possible if you do not observe the optional setup time mentioned in the preceding note.



Parameter	Description
t_c	Cycle time
t_{hw}	Width of low pulse
t_p	Propagation time to valid output data
t_{su}	Setup time
t_h	Hold time

Figure 3-2. External Request Timing Diagram

Handshaking I/O Timing Diagrams

This section compares handshaking I/O protocols and includes timing diagrams for each:

- Handshaking sequence for input operation
- State machine for input operation
- Timing specification for input operation
- Handshaking sequence for output operation
- State machine for output operation
- Timing specification for output operation

Comparing the Different Handshaking Protocols

For an overview of all handshaking protocols supported by your NI 653*X*, refer to Table 3-1.

Note Whether an ACK or a REQ signal occurs first in the handshaking sequence depends on the protocol and the transfer direction.

Table 3-1. Handshaking Protocol Characteristics

Protocol	REQ/ACK Polarity	Which REQ Edge Requests Transfer	Where the Programmable Delay Is Located	Complementary Protocol(s)
Asynchronous Protocols				
8255 Emulation	Active-low	Trailing	Between transfers	Long Pulse
Level ACK	Programmable	Leading	Before ACK and between transfers	Level ACK
Leading-Edge	Programmable	Leading	Before ACK and between transfers	Leading Edge
Long Pulse	Programmable	Leading	Pulse width and between transfers	Long Pulse, 8255 Emulation, and 8255
Trailing-Edge	Programmable	Trailing	Pulse width and between transfers	Trailing-Edge

Table 3-1. Handshaking Protocol Characteristics (Continued)

Protocol	REQ/ACK Polarity	Which REQ Edge Requests Transfer	Where the Programmable Delay Is Located	Complementary Protocol(s)
Synchronous Protocol				
Burst	Programmable	Neither (level REQ)	Clock speed	Burst

* Asynchronous protocols can compensate automatically to cable length, yet for synchronous protocols, select an appropriate speed for your cable when configuring your device.

Select a delay of at least the following:

- 0 for a typical cable up to 1 m
- 1 (70 ns) for a typical cable up to 5 m
- 2 (140 ns) for a typical cable up to 15 m long

For the NI 653*X* to communicate with peripheral devices in handshaking mode, you must verify the following items:

- You are using complementary protocols. For example, use 8255-emulation protocol with long-pulse protocol.
- The ACK/REQ polarity are the same. For example, 8255 emulation is active low only, so the other device must use the long-pulse protocol and have active low ACK/REQ polarity.

Using the Burst Protocol

Burst protocol is a synchronous, or clocked, protocol. In addition to using the ACK and REQ signals like the other handshaking protocols, in burst protocol, the NI 653*X* and the peripheral device share a clock signal over the PCLK line.

The NI 653*X* asserts the ACK signal if it is ready to perform a transfer. If the peripheral device also asserts the REQ signal indicating it is ready, a transfer occurs on the rising edge of the PCLK signal. Refer to Figures 3-3 and 3-4 for examples of burst protocol transfers. Dashed lines indicate when data is transferred.

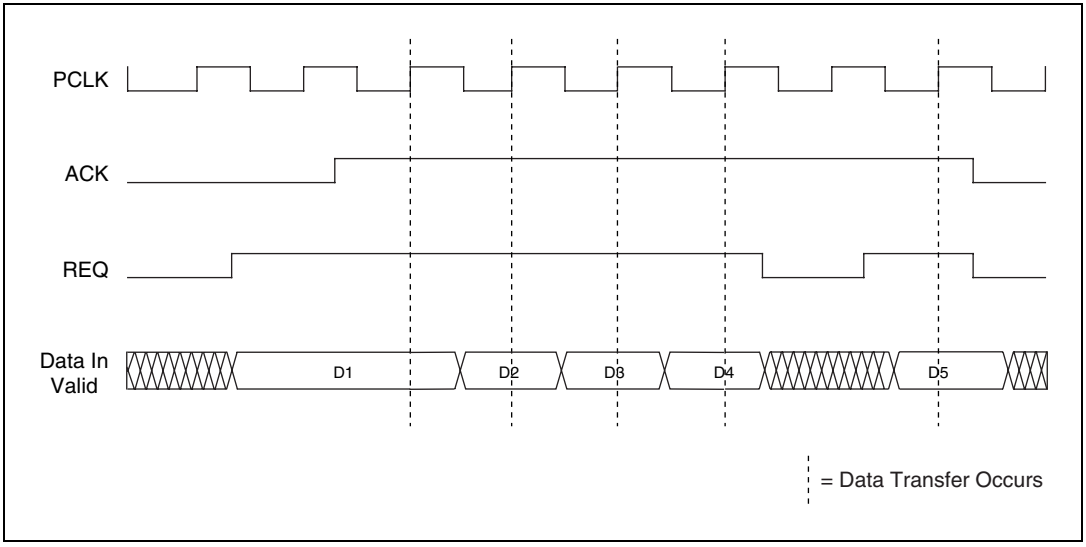


Figure 3-3. Burst Transfer Example (Input)

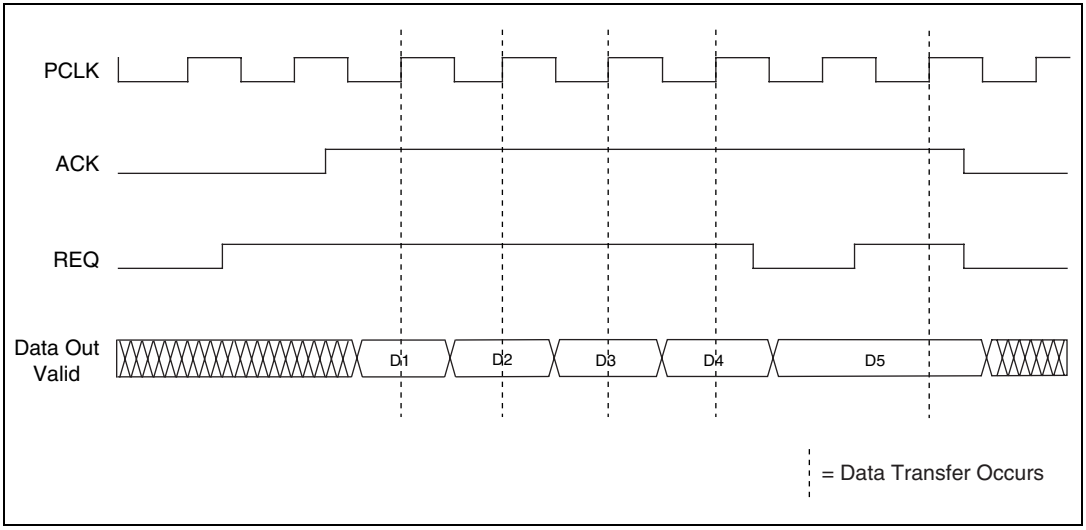
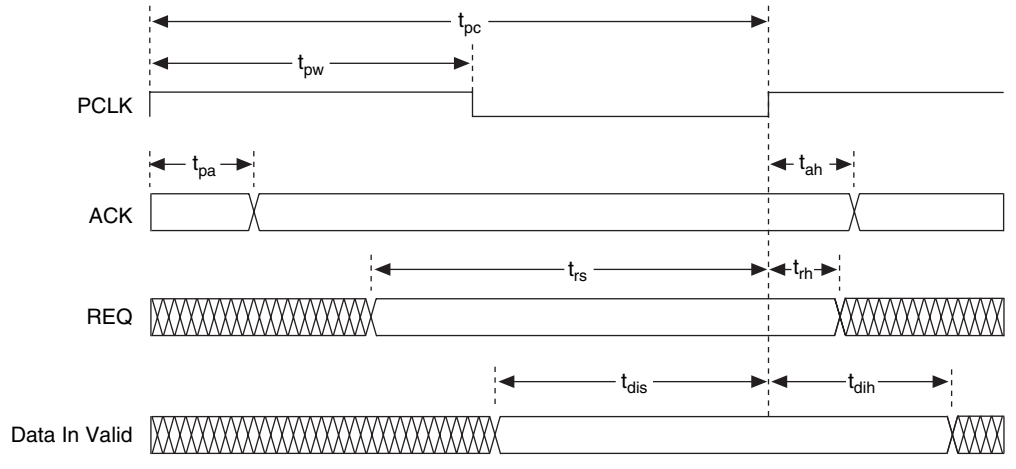


Figure 3-4. Burst Transfer Example (Output)

Note Data is transferred only when both the NI 653*X* and the peripheral device are ready (and thus ACK and REQ are asserted), so it is not reasonable to expect data to arrive at consistent intervals. If consistent intervals are an important criteria for your application, use pattern I/O.

The NI 653*X* can either drive an output clock signal onto the PCLK line or receive an input clock signal from the PCLK line. By default, the PCLK line is set for input during output transfers and for output during input transfers.

Tip If you are using long cables, slow the PCLK clock signal to compensate for the decrease in data setup time.

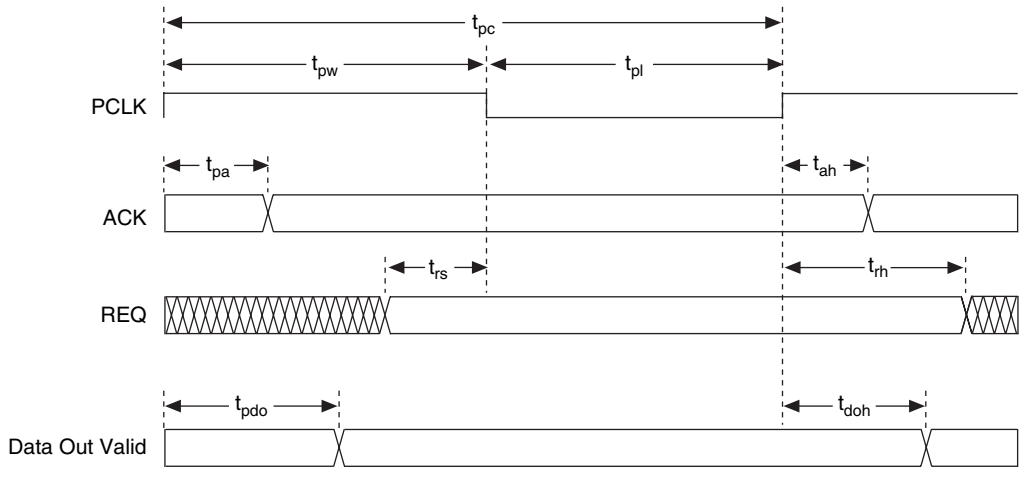


Parameter	Description	Minimum	Maximum
Input Parameters			
t_{rs}	Setup time from REQ valid to PCLK	12	—
t_{rh}	Hold time from PCLK to REQ invalid	0	—
t_{dis}	Setup time from input data valid to PCLK	4	—
t_{dih}	Hold time from PCLK to input data invalid	6	—
Output Parameters			
t_{pc}	PCLK cycle time	50	700[1]
t_{pw}	PCLK high pulse duration	$t_{pc}/2 - 5$	$t_{pc}/2 + 5$
t_{pa}	PCLK to ACK valid	—	18
t_{ah}	Hold time from PCLK to ACK invalid	3	—

[1] t_{pc} = programmable delay from 100 to 700 ns, or 50 ns if programmable delay is 0. Timebase stability for the onboard 20 MHz clock source is 50 ppm.

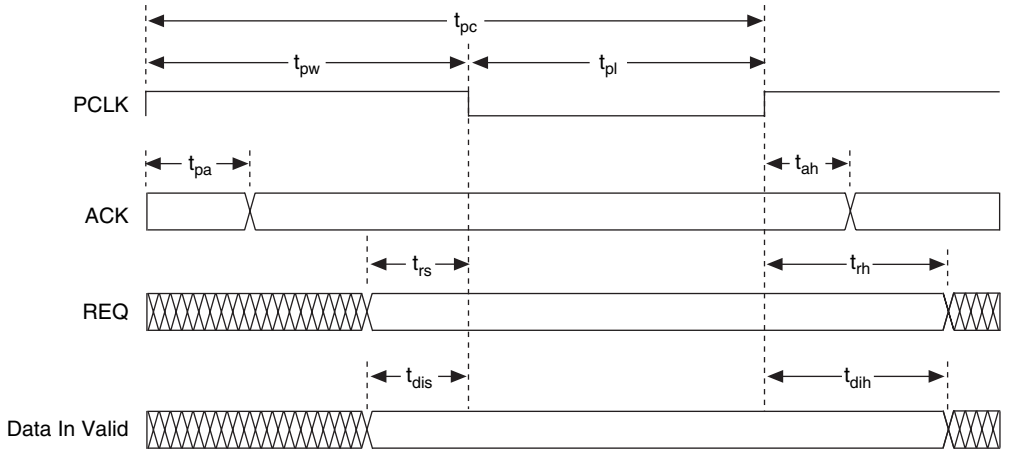
All timing values are in nanoseconds.

Figure 3-5. Burst Input Timing Diagram (Default)



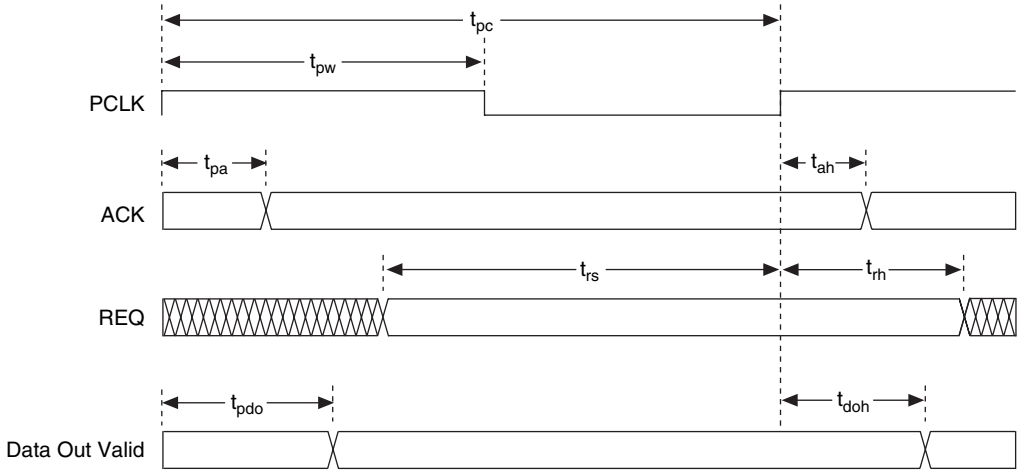
Parameter	Description	Minimum	Maximum
Input Parameters			
t_{pc}	PCLK cycle time	50	—
t_{pw}	PCLK high pulse duration	20	—
t_{pl}	PCLK low pulse duration	20	—
t_{rs}	Setup time from REQ valid to PCLK falling edge	1	—
t_{rh}	Hold time from PCLK to REQ invalid	0	—
Output Parameters			
t_{pa}	PCLK to ACK valid	—	22
t_{ah}	Hold time from PCLK to ACK invalid	3	—
t_{pdo}	PCLK to output data valid	—	28
t_{doh}	Hold time from PCLK to output data invalid	5	—
All timing values are in nanoseconds.			

Figure 3-6. Burst Output Timing Diagram (Default)



Parameter	Description	Minimum	Maximum
Input Parameters			
t_{pc}	PCLK cycle time	50	—
t_{pw}	PCLK high pulse duration	20	—
t_{pl}	PCLK low pulse duration	20	—
t_{rs}	Setup time from REQ valid to PCLK falling edge	1	—
t_{rh}	Hold time from PCLK to REQ invalid	0	—
t_{dis}	Setup time from input data valid to PCLK falling edge	0	—
t_{dih}	Hold time from PCLK to input data valid	0	—
Output Parameters			
t_{pa}	PCLK to ACK valid	—	22
t_{ah}	Hold time from PCLK to ACK invalid	3	—
All timing values are in nanoseconds.			

Figure 3-7. Burst Input Timing Diagram (PCLK Reversed)



Parameter	Description	Minimum	Maximum
Input Parameters			
t_{rs}	Setup time from REQ valid to PCLK	12	—
t_{rh}	Hold time from PCLK to REQ invalid	0	—
Output Parameters			
t_{pc}	PCLK cycle time	50	700[1]
t_{pw}	PCLK high pulse duration	$t_{pc}/2 - 5$	$t_{pc}/2 + 5$
t_{pa}	PCLK to ACK valid	—	18
t_{ah}	Hold time from PCLK to ACK invalid	3	—
t_{pdo}	PCLK to output data valid	—	28
t_{doh}	Hold time from PCLK to output data invalid	4	—
t_{dis}	Setup time from input data valid to PCLK	0	—
t_{dih}	Hold time from PCLK to input data invalid	0	—

[1] t_{pc} = programmable delay from 100 to 700 ns, or 50 ns if programmable delay is 0. Timebase stability for the onboard 20 MHz clock source is 50 ppm.

All timing values are in nanoseconds.

Figure 3-8. Burst Output Timing Diagram (PCLK Reversed)

Using Asynchronous Protocols

All handshaking protocols except burst are asychronous. The asynchronous protocols include 8255 emulation, level ACK, leading edge, trailing edge, and long pulse.

When using these protocols, you have the following options:

- You can change the polarity of the ACK and REQ signals (except for 8255-emulation). The diagrams in this chapter show active high signals.
- You can set a programmable delay, from 0 to 700 ns, programmable in increments of 100 ns. Use the programmable delay to insert wait states if you have a slow peripheral device. A delay increases the duration of each transfer. The location of the delay in the handshaking sequence differs from protocol to protocol. In addition, a delay increases the minimum spacing between consecutive transfers.
- You can enable request-edge latching, where in input, the NI 653*X* latches data in from the I/O connector on the active REQ edge before reading the data. For output, after writing the data, the NI 653*X* latches data out of the I/O connector on the active REQ edge. The active edge of the REQ is determined (rising or falling) by the handshaking protocol and the REQ polarity.

Using the 8255-Emulation Protocol

Your NI 653*X* can perform handshaking I/O with devices that contain the 8255 chip, including the National Instruments NI PC-DIO-24/PnP, NI 650*X* family, and NI PC-DIO-96/PnP. Performing the 8255-emulation protocol with your NI 653*X* is similar to 8255 or 82C55 Programmable Peripheral Interface (PPI).

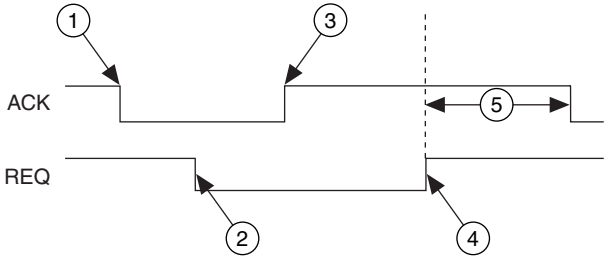
Note The NI 653*X* does not emulate the bidirectional protocol of an 8255 device.

The NI 653*X* can perform back-to-back transfers much faster than a true 8255-based device. If your peripheral device requires more time between transfers, configure the NI 653*X* to add a data-settling delay between transfers.

Note In the 8255-emulation protocol, ACK and REQ are active low, reflected in the following timing diagrams. For all other handshaking I/O protocols, the polarities of ACK and REQ are programmable, but are shown as active high signals in the following diagrams.

NI 653*X* terminology differs from 8255 terminology.

- Input—The REQ line carries the 8255 STB (Strobe) input signal, and the NI 653*X* ACK line carries the 8255 IBF (Input Buffer Full) output signal.
- Output—The REQ line carries the 8255 $\overline{\text{ACK}}$ input signal, and the NI 653*X* ACK line carries the 8255 $\overline{\text{OBF}}$ (Output Buffer Full) output signal.



ACK and REQ are shown as active low.
Steps 1-5 are repeated for each transfer.

Reference Point	Action Steps
1	The NI 653*X* asserts the ACK signal when ready to accept data.
2	The peripheral device can then strobe data into the NI 653*X* by asserting the REQ line. This assertion can happen before or after ACK is asserted.
3	Asserting the REQ signal causes the ACK signal to deassert.
4	Deasserting the REQ signal causes the NI 653*X* to latch input data.
5	The NI 653*X* reasserts the ACK signal when it has space and is ready for another input. A programmable delay can be inserted here.

Figure 3-9. 8255-Emulation Input Handshaking Sequence

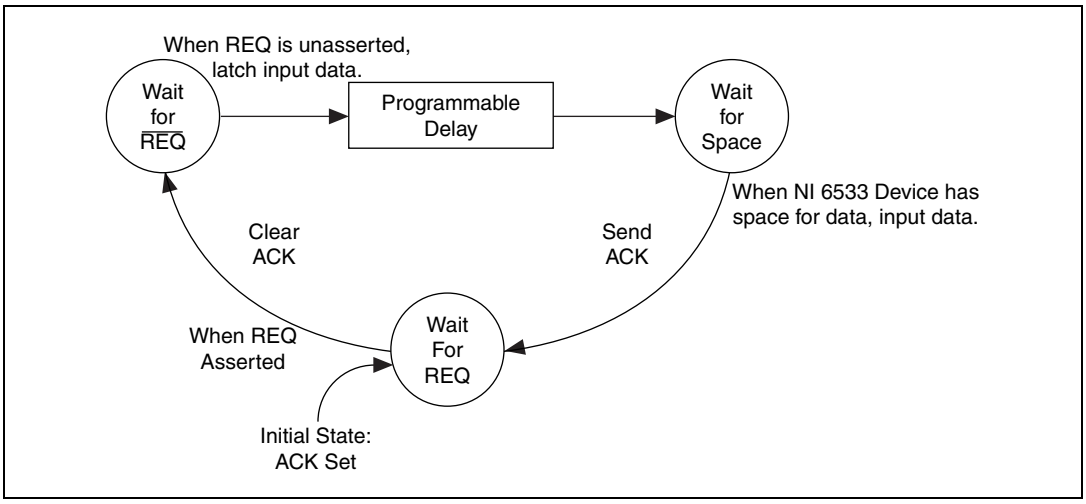
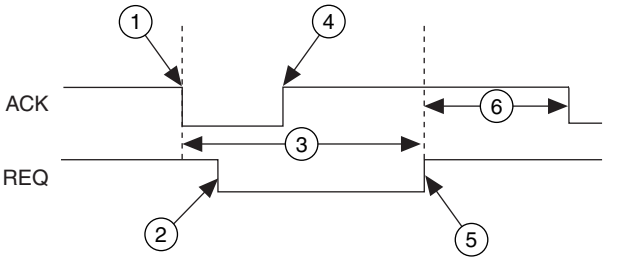


Figure 3-10. 8255-Emulation Input State Machine



ACK and REQ are shown as active low.
Steps 1-6 are repeated for each transfer.

Reference Point	Action Steps
1	When the NI 653*X* has data to output, it asserts the ACK signal, then waits for the peripheral device to assert REQ to indicate it is ready to accept data.
2	The peripheral device asserts a REQ signal to accept the data.
3	The peripheral device can receive the data on the falling or rising edge of the ACK signal or any time in between before the next rising edge on REQ.
4	The REQ signal edge in step 2 causes the ACK signal to return to deassert.
5	The rising REQ signal edge enables a new transfer to occur. The peripheral device should wait until it has received data before deasserting the REQ signal. The peripheral device can also wait for the ACK signal to deassert before deasserting the REQ line.
6	The NI 653*X* reasserts the ACK signal when it has data and is ready for another output. A programmable delay can be inserted here. **Note**: The DIO-32HS drops the ACK line to indicate that the NI 653*X* is ready to receive data regardless of whether or not "count" has been reached. The output device controls the timing of the transfer by dropping the REQ line when it is ready to transfer data. The timing is not controlled by the software.

Figure 3-11. 8255-Emulation Output Handshaking Sequence

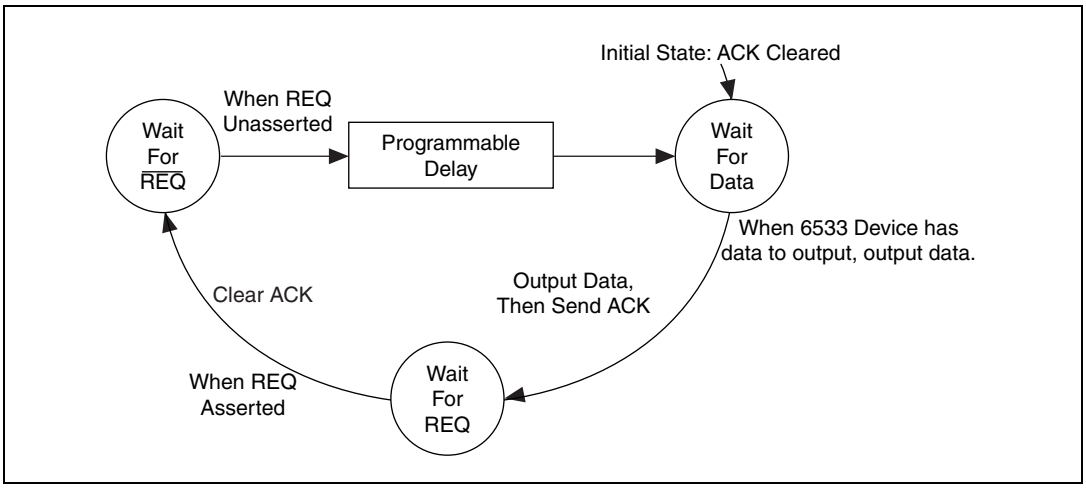
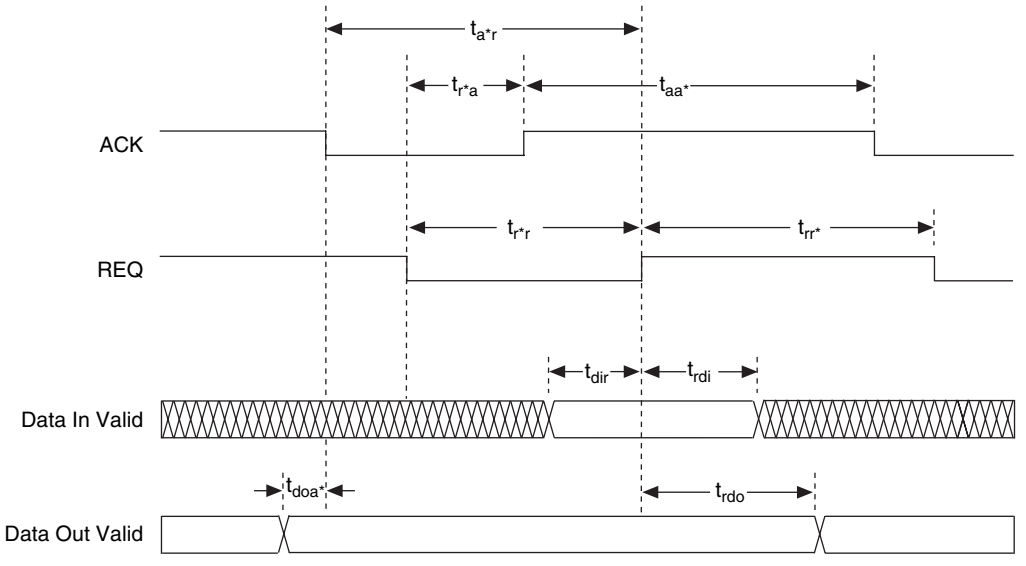


Figure 3-12. 8255-Emulation Output State Machine



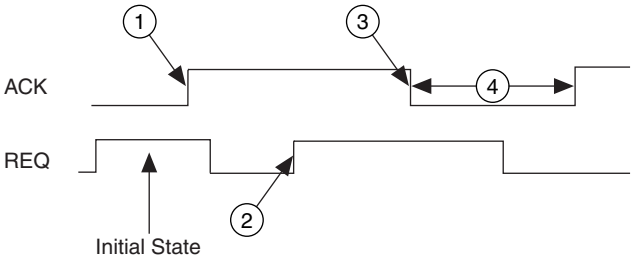
ACK and REQ are shown as active low

Parameter	Description	Minimum	Maximum
Input Parameters			
t_{r*r}	REQ low duration	75	—
t_{rr*}	REQ high duration	75	—
t_{a*r}	ACK falling edge to REQ rising edge	0	—
t_{dir}	Input data valid to REQ rising edge	0	—
t_{rdi}	REQ rising edge to input data invalid	10	—
Output Parameters			
t_{aa*}	ACK high duration	100	—
t_{r*a}	REQ falling edge to ACK rising edge	—	150
t_{doa*}	Output data valid to ACK falling edge	25	—
t_{rdo}	REQ rising edge to output data invalid	100	—
All timing values are in nanoseconds.			

Figure 3-13. 8255-Emulation Input/Output Timing Diagram

Using the Level-ACK Protocol

In level-ACK protocol, the NI 653*X* asserts the ACK signal when ready for a transfer and holds the ACK signal level until an active-going edge occurs on the REQ line. After the REQ edge occurs, the NI 653*X* deasserts the ACK signal until the device is ready for another transfer.



ACK and REQ are shown as active high.
Steps 1-4 are repeated for each transfer.

Reference Point	Action Steps
Initial State	ACK is deasserted. The NI 653*X* waits for an active REQ to indicate that the peripheral device is ready. The peripheral device may optionally drive the first data at this time. The transfer cannot begin until the peripheral asserts REQ; the peripheral may either pulse REQ or hold REQ high until the first ACK occurs. If the peripheral pulses REQ, make sure to start the transfer on the NI 653*X* before the pulse occurs to avoid missing the pulse.
1	The NI 653*X* waits until it has space for data, then it asserts ACK.
2	The peripheral device can then strobe data into the NI 653*X* by first deasserting then asserting the REQ signal. The NI 653*X* waits for an active-going transition on the REQ line. ACK stays asserted, indicating the NI 653*X* is ready, until the active-going REQ occurs.
3	The active-going REQ signal edge deasserts the ACK signal and causes the NI 653*X* to latch input data.
4	To slow down the data transfer, you can insert a programmable delay before the ACK signal is asserted.

Figure 3-14. Level-ACK Input Handshaking Sequence

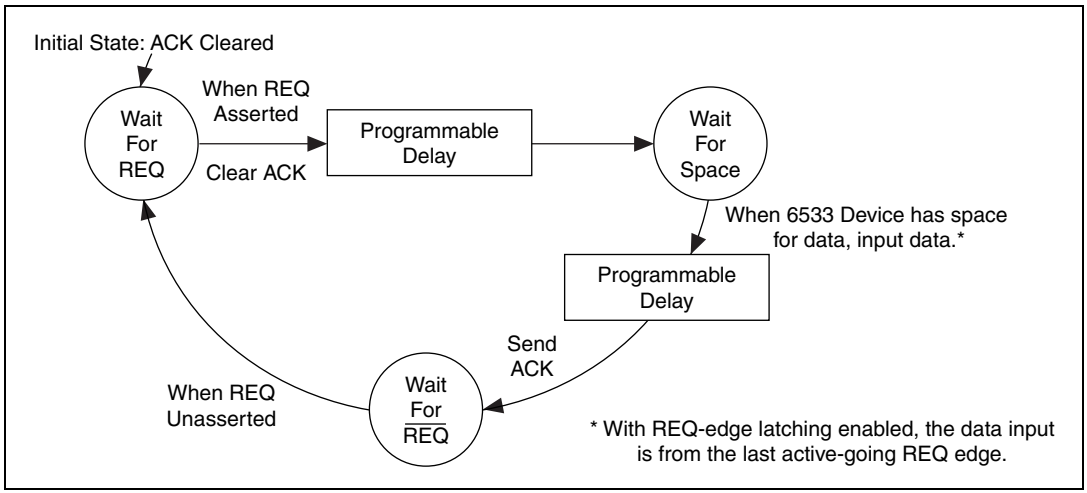
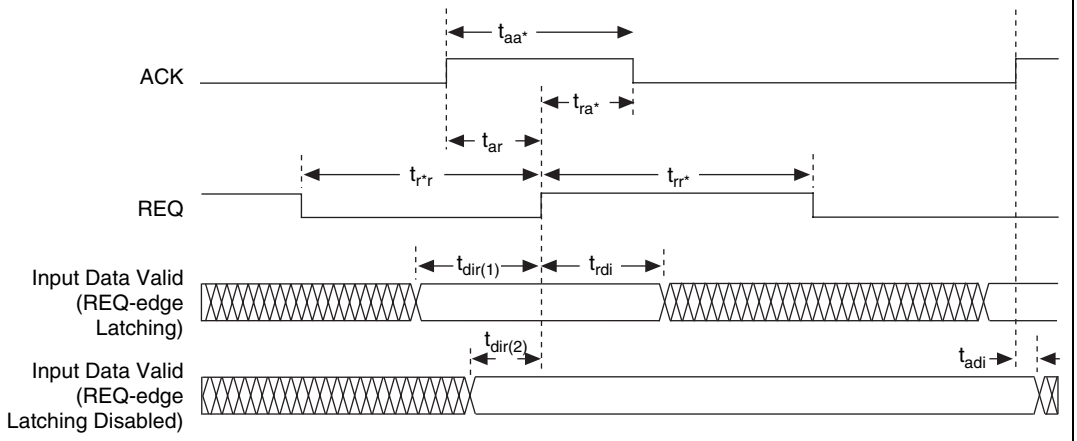


Figure 3-15. Level-ACK Input State Machine

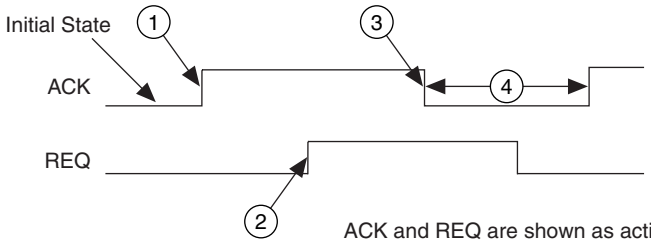


ACK and REQ are shown as active high.

Parameter	Description	Minimum	Maximum
Input Parameters			
t_{rr*}	REQ pulse width	75	—
t_{r*r}	REQ inactive duration	75	—
t_{ar}	ACK to next REQ	0	—
$t_{dir(1)}$	Input data setup to REQ active (with REQ-edge latching)	0	—
t_{rdi}	Input data hold from REQ active (with REQ-edge latching)	10	—
$t_{dir(2)}$	Input data setup to REQ (with REQ-edge latching disabled)	0	—
t_{adi}	Input data hold from ACK (with REQ-edge latching disabled)	0	—
Output Parameters			
t_{aa*}	ACK pulse width	225	—
t_{ra*}	REQ to ACK inactive	100	200
All timing values are in nanoseconds.			

Figure 3-16. Level-ACK Input Timing Diagram

Note With REQ-edge latching enabled (default), the REQ edge determines when data is latched. Input data valid has to be held before the active-going REQ edge a minimum of t_{rdi} ns. With REQ edge disabled, input data valid has to be held t_{adi} after the next active-going ACK signal edge is asserted.



Reference Point	Action Steps
Initial State	ACK is deasserted.
1	When the NI 653*X* has data to output, it drives the data onto the data lines, and then asserts ACK. ACK stays asserted, indicating the NI 653*X* is ready, until the active-going REQ edge occurs.
2	The peripheral device responds with an active-going REQ signal edge. ACK stays asserted, indicating the NI 653*X* is ready, until the active-going REQ occurs. Since the REQ is already asserted, the NI 653*X* waits until REQ deasserts and reasserts to deassert the ACK signal and request additional data.
3	The asserted REQ signal deasserts the ACK signal.
4	To slow down the data transfer, you can insert a programmable delay before the ACK signal is asserted.

Figure 3-17. Level-ACK Output Handshaking Sequence

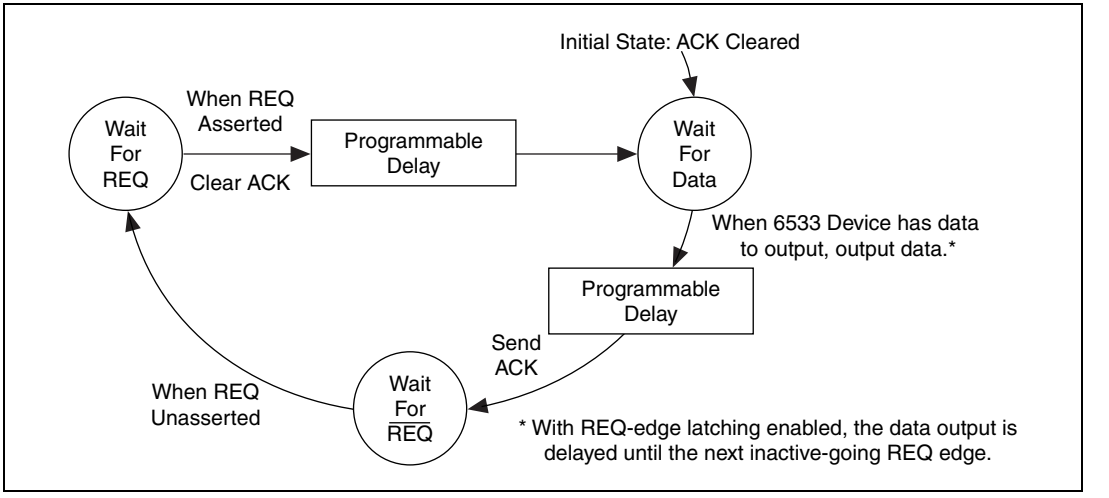
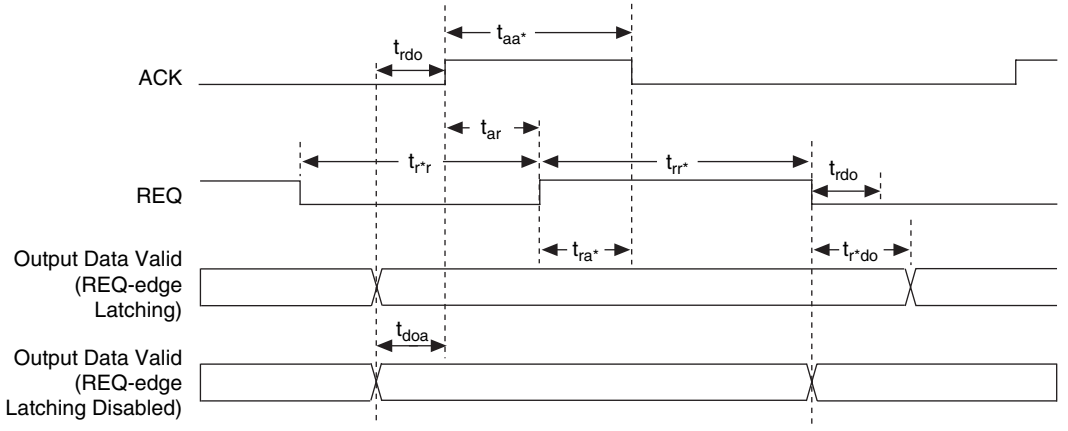


Figure 3-18. Level-ACK Output State Machine



Parameter	Description	Minimum	Maximum
Input Parameters			
t_{rr*}	REQ pulse width	75	—
t_{r*r}	REQ inactive duration	75	—
t_{ar}	ACK to next REQ	0	—
Output Parameters			
t_{aa*}	ACK pulse width	225	—
t_{ra*}	REQ to ACK inactive	100	200
t_{r*do}	REQ inactive to new output data (with REQ-edge latching)	0	50
t_{rdo}	REQ to new output data (with REQ-edge latching disabled)	0	—
t_{doa}	Output data valid to ACK (with REQ-edge latching disabled)	25[1]	—

[1] t_{doa} (min.) = 25 + programmable delay

Figure 3-19. Level-ACK Output Timing Diagram

Note With REQ-edge latching disabled (default), output data valid holds t_{rdo} ns after the REQ edge is asserted. With REQ-edge latching enabled, that data is held for at most t_{rdo} ns after the REQ edge deasserts.

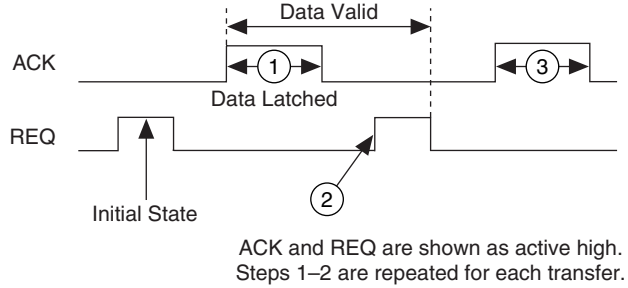
Using Protocols Based on Signal Edges

The NI 653*X* can communicate using pulses on the ACK and REQ lines. The three edge protocols are:

- Trailing-edge protocol—The trailing edge of the ACK or REQ pulse indicates that the NI 653*X* or peripheral device is ready for a transfer.
- Leading-edge protocol—The rising edge of the ACK or REQ pulse indicates that the NI 653*X* or peripheral device is ready for a transfer.
- Long-pulse protocol—This protocol is a variant of the leading-edge protocol, with the additional option of using a data-settling delay. If your application requires a large minimum pulse width, use this protocol. In this case, the programmable delay is used to increase the ACK pulse width instead of delaying the ACK pulse.

You can also use long-pulse protocol to handshake with an actual 8255 or 82C55 PPI. You must set the ACK and REQ signals to active low and select a minimum pulse width of 500 ns for your 8255 or 82C55.

Using the Trailing-Edge Protocol



Reference Point	Action Steps
Initial State	ACK is deasserted. The NI 653*X* waits for the peripheral device to pulse REQ to indicate it has data.
1	The NI 653*X* sends an ACK pulse of programmable width when ready to receive data.
2	After receiving the trailing edge of the ACK pulse, the peripheral device can strobe data into the NI 653*X* and pulse the REQ.
3	The NI 653*X* sends another ACK pulse when ready for another input.

Figure 3-20. Trailing-Edge Input Handshaking Sequence

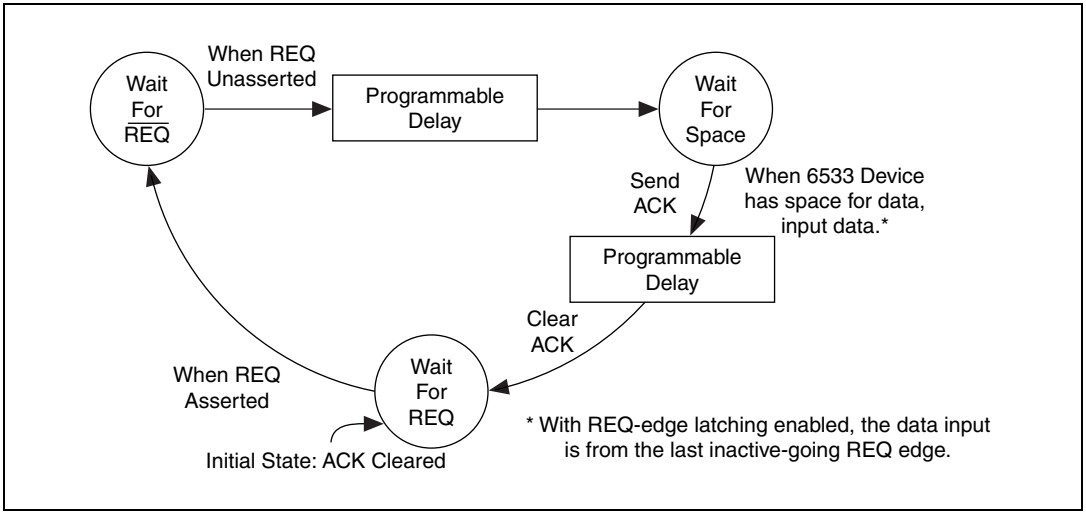
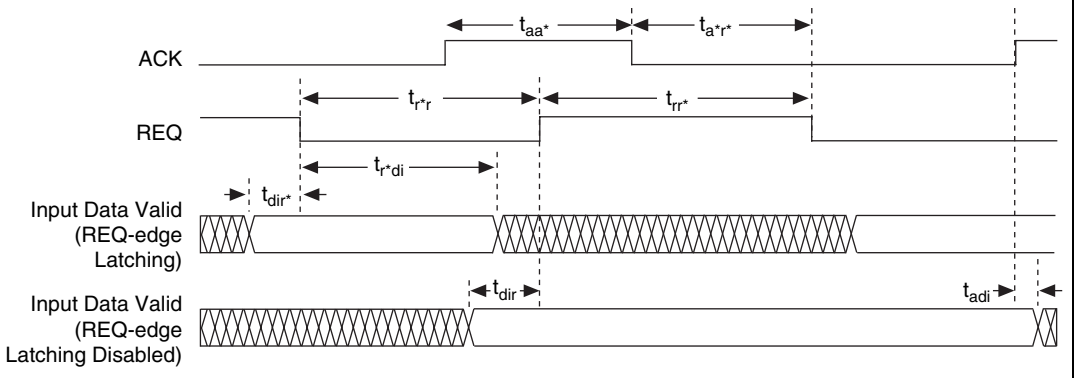


Figure 3-21. Trailing-Edge Input State Machine



ACK and REQ are shown as active high.

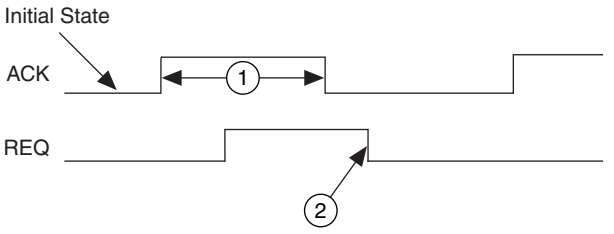
Parameter	Description	Minimum	Maximum
Input Parameters			
t_{rr*}	REQ pulse width	75	—
t_{r*r}	REQ inactive duration	75	—
t_{dir*}	Input data setup to REQ inactive (with REQ-edge latching)	0	—
t_{r*di}	Input data hold from REQ inactive (with REQ-edge latching)	10	—
t_{dir}	Input data setup to REQ (with REQ-edge latching disabled)	0	—
t_{adi}	Input data hold from ACK (with REQ-edge latching disabled)	0	—
Output Parameters			
t_{aa*}	ACK pulse width	225[1]	275[2]
t_{a*r*}	ACK inactive to next REQ inactive	0	—

[1] t_{aa*} (min.) = 225 + programmable delay

[2] t_{aa*}(max) = 275 + programmable delay

Figure 3-22. Trailing-Edge Input Timing Diagram

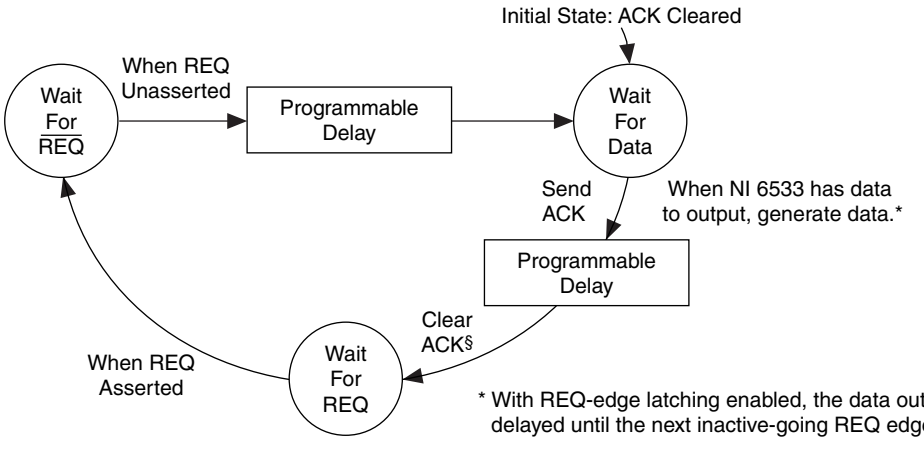
Note When REQ-edge latching is enabled (default), the REQ edge determines when data will be latched. Input data valid must be held t_{r*di} after the trailing edge of REQ occurs. When REQ-edge latching is disabled, input data valid needs to be held t_{adi} after the active-going edge of the ACK signal occurs.



ACK and REQ are shown as active high.
Steps 1-2 are repeated for each transfer.

Reference Point	Action Steps
Initial State	ACK is deasserted.
1	The NI 653*X* sends an ACK pulse of programmable width. This pulse indicates new, valid output data.
2	The peripheral device responds with a REQ pulse. The trailing edge of the REQ pulse deasserts the ACK signal if it has not previously been deasserted and requests additional data.

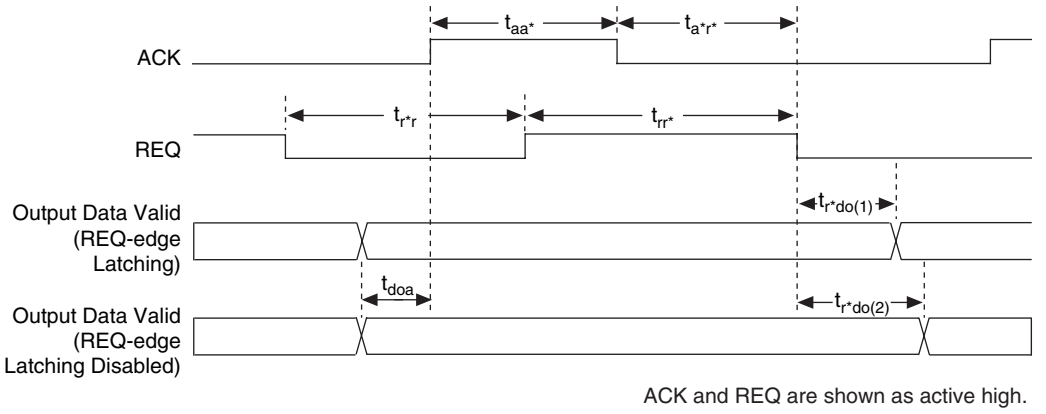
Figure 3-23. Trailing-Edge Output Handshaking Sequence



* With REQ-edge latching enabled, the data output is delayed until the next inactive-going REQ edge.

§ The programmable delay determines which ACK is cleared, ACK does not need to be cleared before REQ can be acknowledged.

Figure 3-24. Trailing-Edge Output State Machine



Parameter	Description	Minimum	Maximum
Input Parameters			
t_{rr*}	REQ pulse width	75	—
t_{r*r}	REQ inactive duration	75	—
t_{a*r*}	ACK inactive to next REQ inactive	0	—
Output Parameters			
t_{aa*}	ACK pulse width	225[1]	275[2]
$t_{r*do(1)}$	REQ inactive to new output data (with REQ-edge latching)	0	50
$t_{r*do(2)}$	REQ inactive to new output data (with REQ-edge latching disabled)	0	—
t_{doa}	Output data valid to ACK (with REQ-edge latching disabled)	25	—

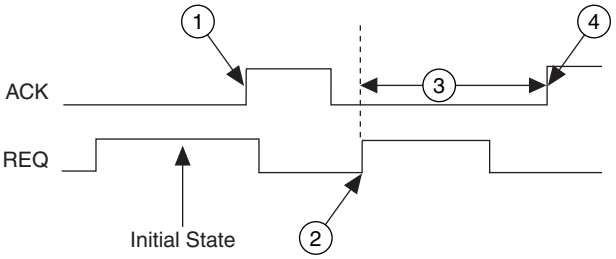
[1] t_{aa*} (min) = 225 + programmable delay

[2] t_{aa*} (max) = 275 + programmable delay

Figure 3-25. Trailing-Edge Output Timing Diagram

Note When REQ-edge latching is disabled (default), output valid data is held $t_{r*do(1)}$ ns after the trailing edge of REQ occurs. With REQ-edge latching enabled, output data will be at most $t_{r*do(1)}$ ns after the trailing edge of REQ occurs.

Using the Leading-Edge Protocol



ACK and REQ are shown as active high.
Steps 1-3 are repeated for each transfer.

Reference Point	Action Steps
Initial State	ACK is deasserted. The NI 653*X* waits for an active REQ to indicate that the peripheral device is ready. The peripheral device may optionally drive the first data at this time. The transfer cannot begin until the peripheral asserts REQ: the peripheral can either pulse REQ or hold REQ high until the first ACK occurs. If the peripheral pulses REQ, make sure to start the transfer on the NI 653*X* before the pulse occurs, to avoid missing the pulse.
1	The NI 653*X* sends an ACK pulse when it is ready to receive data. The ACK pulse width is fixed, assuming the peripheral device has deasserted the REQ signal. Otherwise the ACK signal remains asserted until the REQ signal deasserts.
2	After receiving at least the leading edge of the ACK pulse, the peripheral device can strobe data into the NI 653*X* by asserting REQ.
3	To slow down the data transfer, you can insert a programmable delay before the ACK signal is asserted.
4	The NI 653*X* sends another ACK when it is ready for another input.

Figure 3-26. Leading-Edge Input Handshaking Sequence

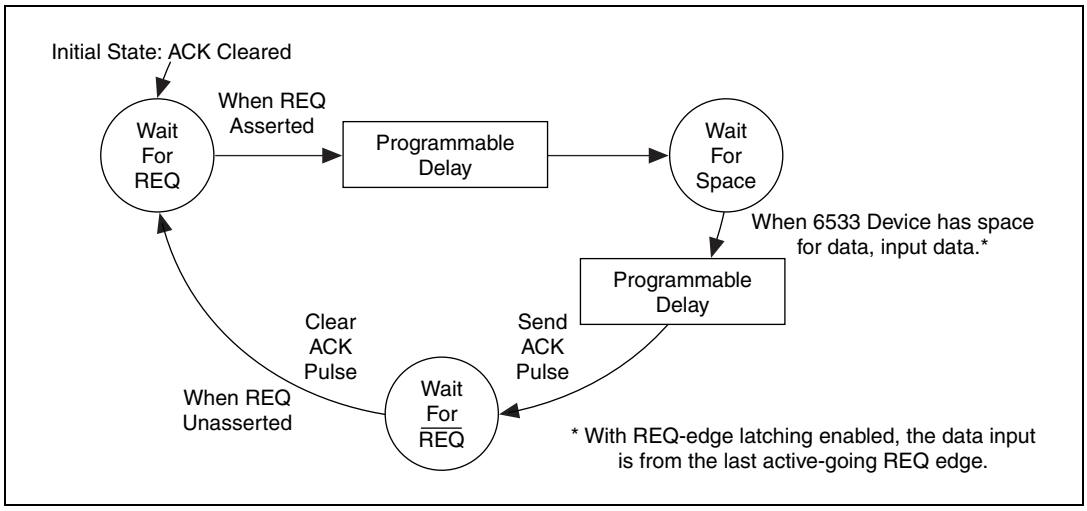
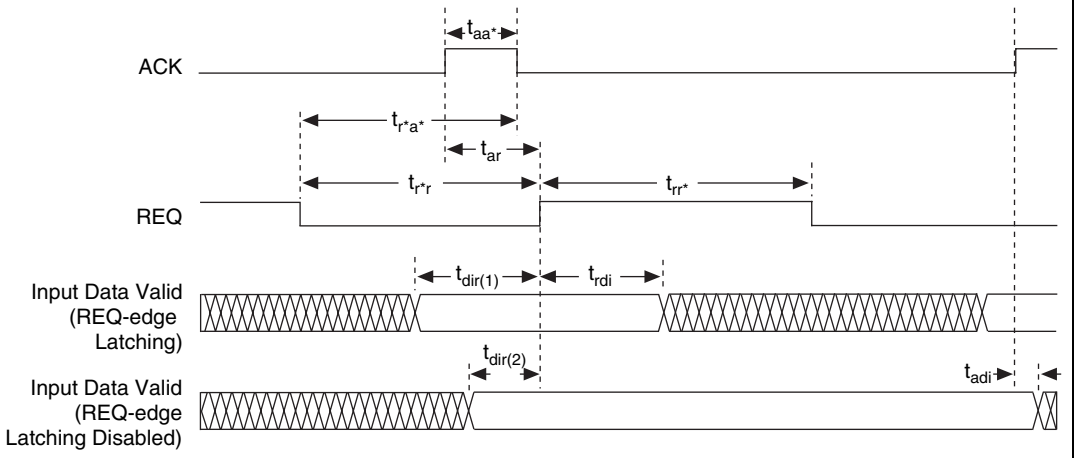


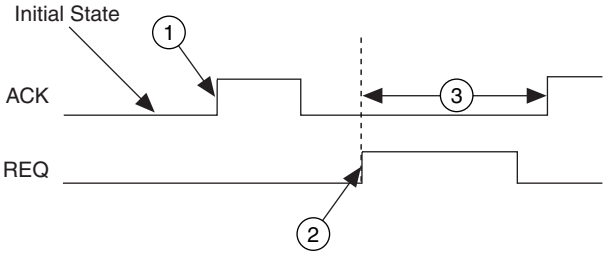
Figure 3-27. Leading-Edge Input State Machine



Parameter	Description	Minimum	Maximum
Input Parameters			
t_{rr*}	REQ pulse width	75	—
t_{r*r}	REQ inactive duration	75	—
t_{ar}	ACK to next REQ	0	—
$t_{dir(1)}$	Input data setup to REQ active (with REQ-edge latching)	0	—
t_{rdi}	Input data hold from REQ active (with REQ-edge latching)	10	—
$t_{dir(2)}$	Input data setup to REQ (with REQ-edge latching disabled)	0	—
t_{adi}	Input data hold from ACK (with REQ-edge latching disabled)	0	—
Output Parameters			
t_{aa*}	ACK pulse width	125	—
t_{r*a*}	REQ inactive to ACK inactive	150	—
All timing values are in nanoseconds.			

Figure 3-28. Leading-Edge Input Timing Diagram

Note With REQ-edge latching enabled (default), the REQ edge determines when data is latched. Input data valid must be held before an active-going REQ edge for a minimum of t_{rdi} ns. With REQ edge disabled, it must be held t_{adi} after the next active-going ACK signal edge occurs.



ACK and REQ are shown as active high.
Steps 1-3 are repeated for each transfer.

Reference Point	Action Steps
Initial State	ACK is deasserted.
1	The NI 653*X* sends the ACK pulse after driving output data to indicate that it has new, valid output data. The ACK pulse width is fixed, assuming the peripheral device has deasserted the REQ signal. Otherwise, the ACK signal remains asserted until the peripheral device deasserts the REQ signal.
2	Once the data is latched, the peripheral device must respond with an active-going REQ signal edge to request additional data.
3	To slow down the data transfer, you can insert a programmable delay before the ACK signal is asserted.

Figure 3-29. Leading-Edge Output Handshaking Sequence

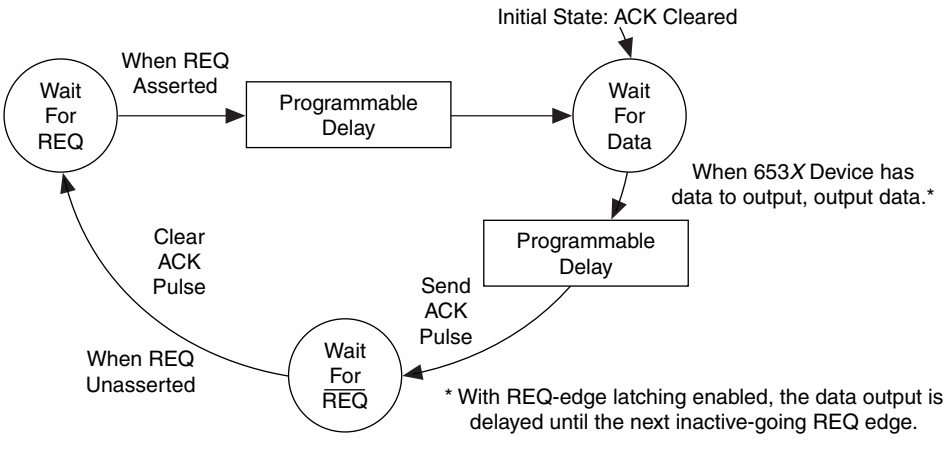
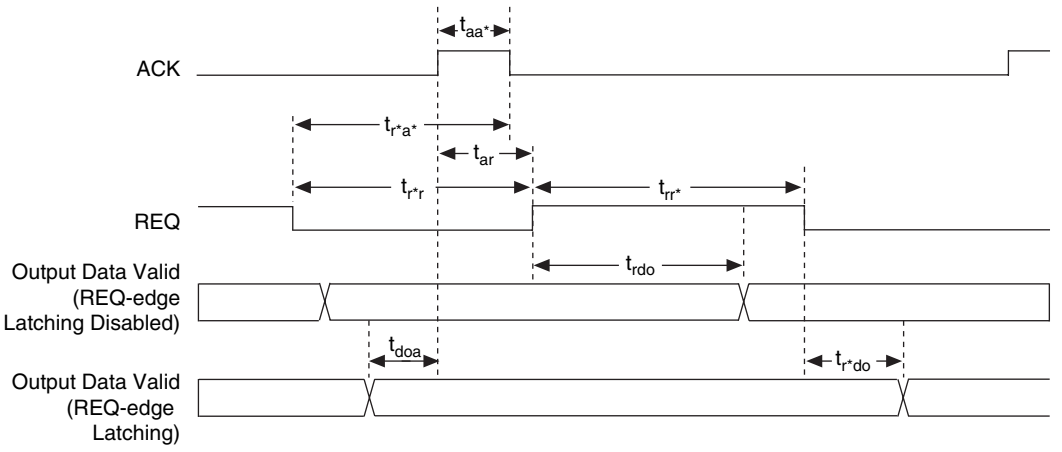


Figure 3-30. Leading-Edge Output State Machine



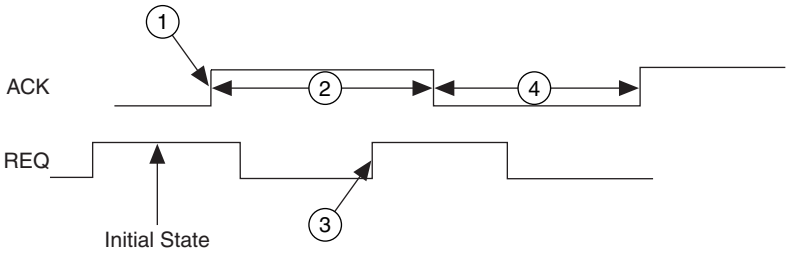
Parameter	Description	Minimum	Maximum
Input Parameters			
t_{rr*}	REQ pulse width	75	—
t_{r*r}	REQ inactive duration	75	—
t_{ar}	ACK to next REQ	0	—
Output Parameters			
t_{aa*}	ACK pulse width	150	—
t_{r*a*}	REQ inactive to ACK inactive	150	—
t_{r*do}	REQ inactive to new output data (with REQ-edge latching)	0	50
t_{rdo}	REQ to new output data (with REQ-edge latching disabled)	0	—
t_{doa}	Output data valid to ACK (with REQ-edge latching disabled)	25[1]	—

[1] t_{doa} (min.) = 25 + programmable delay

Figure 3-31. Leading-Edge Output Timing Diagram

Note With REQ-edge latching disabled (default), output data valid is held t_{rdo} ns after the REQ edge occurs. With REQ-edge latching enabled, that data is held for at most t_{rdo} ns after the REQ edge deasserts.

Using the Long-Pulse Protocol



Reference Point	Action Steps
Initial State	ACK is deasserted. The NI 653*X* waits for an active REQ to indicate that the peripheral device is ready. The peripheral device may optionally drive the first data at this time. The transfer cannot begin until the peripheral asserts REQ: the peripheral may either pulse REQ or hold REQ high until the first ACK occurs. If the peripheral pulses REQ, start the transfer on the NI 653*X* before the pulse occurs to avoid missing the pulse.
1	The NI 653*X* asserts an ACK signal when it is ready to receive data, assuming the peripheral device has deasserted the REQ signal. Otherwise, the ACK signal remains asserted until the REQ signal deasserts.
2	To slow down the data transfer, you can insert a programmable delay before deasserting the ACK signal. Unlike in the leading-edge protocol, the pulse width is programmable.
3	After receiving the leading edge of the ACK pulse, the peripheral device can strobe data into the NI 653*X* by asserting REQ.
4	The same programmable delay that controls the minimum ACK pulse width further slows down the transfer by delaying next occurrence of the next ACK pulse.

Figure 3-32. Long-Pulse Input Handshaking Sequence

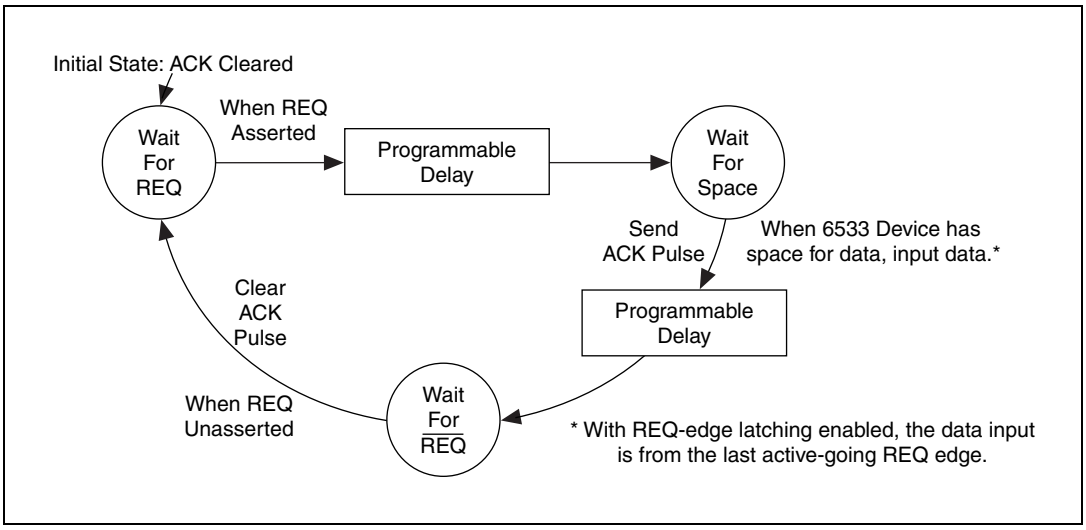
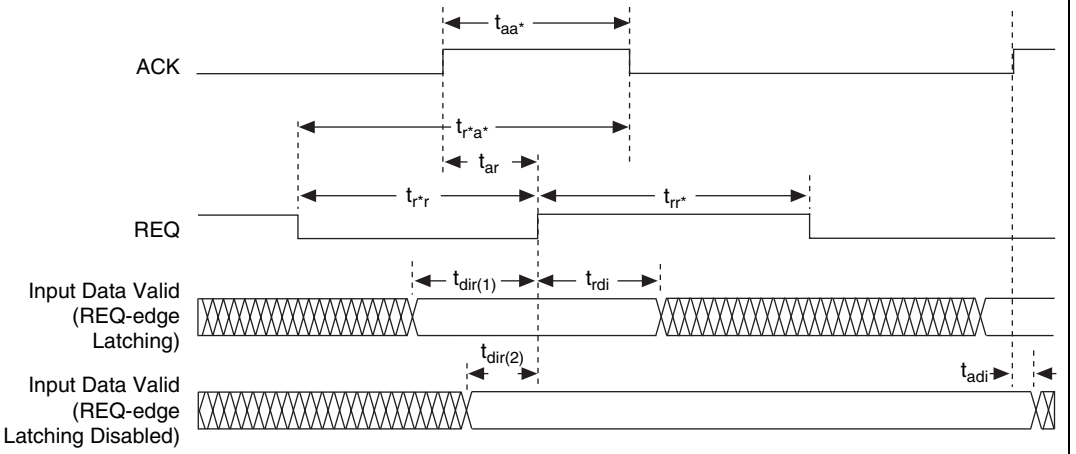


Figure 3-33. Long-Pulse Input State Machine



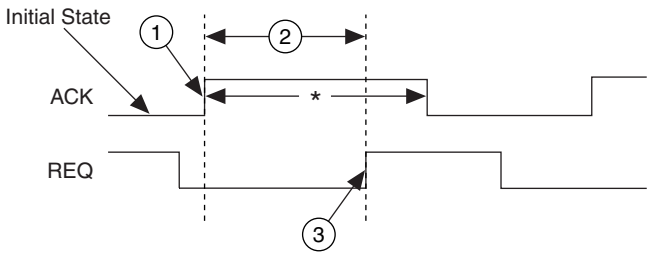
ACK and REQ are shown as active high.

Parameter	Description	Minimum	Maximum
Input Parameters			
t_{rr*}	REQ pulse width	75	—
t_{r*r}	REQ inactive duration	75	—
t_{ar}	ACK to next REQ	0	—
$t_{dir(1)}$	Input data setup to REQ active (with REQ-edge latching)	0	—
t_{rdi}	Input data hold from REQ active (with REQ-edge latching)	10	—
$t_{dir(2)}$	Input data setup to REQ (with REQ-edge latching disabled)	0	—
t_{adi}	Input data hold from ACK (with REQ-edge latching disabled)	0	—
Output Parameters			
t_{aa*}	ACK pulse width	125[1]	—
t_{r*a*}	REQ inactive to ACK inactive	150	—

[1] t_{aa*}(min.) = 125 + programmable delay

Figure 3-34. Long-Pulse Input Timing Diagram

Note With REQ-edge latching enabled (default) REQ edge determines when data is latched. Input data valid must be held before active-going REQ edge a minimum of t_{rdi} ns. With REQ edge disabled, it must be held t_{adi} after the next active-going ACK signal edge occurs.



Reference Point	Action Steps
Initial State	ACK is deasserted.
1	The NI 653*X* sends an ACK pulse with programmable width to indicate that it has data to generate, assuming the peripheral device has deasserted the REQ signal. Otherwise, the ACK signal remains asserted until the peripheral device deasserts the REQ signal.
2	The peripheral device can latch the data on the rising or falling edge of the ACK pulse, or it can latch the data any time before asserting the REQ signal.
3	When the data is latched, the peripheral device must respond with an active-going REQ signal edge.

Figure 3-35. Long-Pulse Output Handshaking Sequence

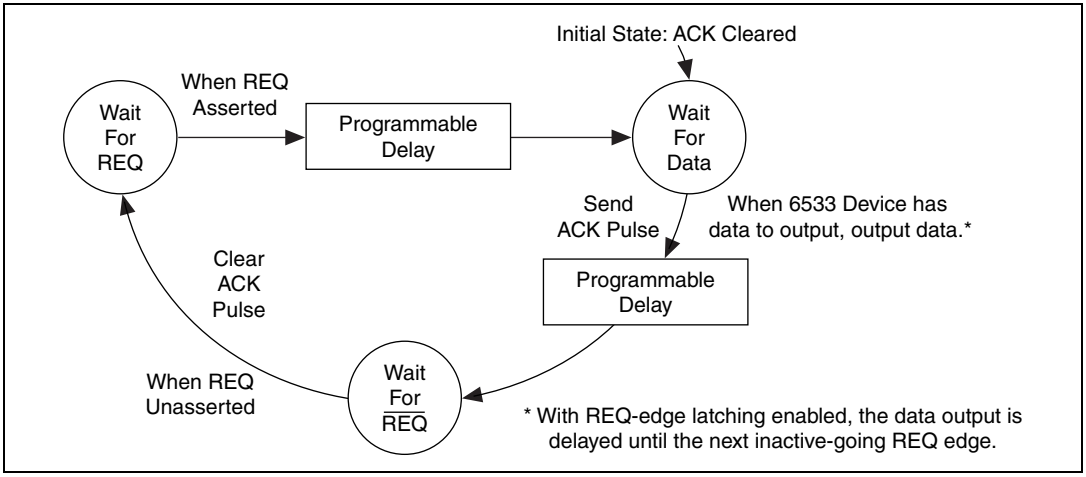
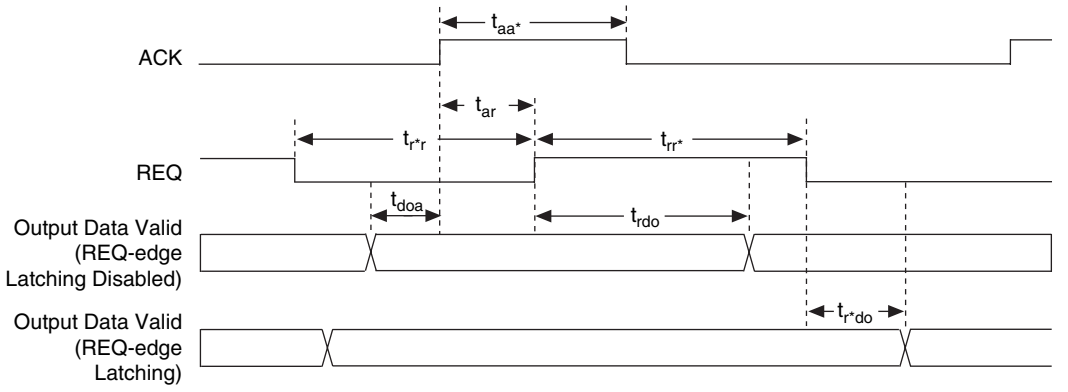


Figure 3-36. Long-Pulse Output State Machine



Parameter	Description	Minimum	Maximum
Input Parameters			
t_{rr*}	REQ pulse width	75	—
t_{r*r}	REQ inactive duration	75	—
t_{ar}	ACK to next REQ	0	—
Output Parameters			
t_{aa*}	ACK pulse width	125[1]	—
t_{r*do}	REQ inactive to new output data (with REQ-edge latching)	0	50
t_{rdo}	REQ to new output data (with REQ-edge latching disabled)	0	—
t_{doa}	Output data valid to ACK (with REQ-edge latching disabled)	25	—

[1] t_{aa*} (min.) = 125 + programmable delay

Figure 3-37. Long-Pulse Output Timing Diagram

Note With REQ-edge latching disabled (default), output data valid is held t_{rdo} ns after the REQ edge with REQ-edge latching enabled that data is held for at most t_{rdo} ns after the REQ edge deasserts.

A

Specifications

This appendix lists features and specifications for the NI 653*X* devices and the NI PCI/PXI-7030/6533. Specifications are typical at 25 °C unless otherwise noted.

Digital I/O

Number of channels ..... 32 input/output;
4 dedicated output and control;
4 dedicated input and status

Compatibility ..... TTL/CMOS (standard or open collector)

Hysteresis ..... 500 mV

Digital logic levels

Level	Min	Max
Input low voltage	0 V	0.8 V
Input high voltage	2 V	5 V
Input low current for data lines (V_{in} = 0.4 V) DPULL high DPULL low	 — —	 –70 µA –10 µA
Input high current for data lines (V_{in} = 2.4 V) DPULL high DPULL low	 — —	 10 µA 40 µA
Input low current for control lines (V_{in} = 0.4 V) CPULL high CPULL low	 — —	 –2.5 mA –200 µA

Level (Continued)	Min	Max
Input high current for control lines (V_{in} = 2.4 V) CPULL high CPULL low	 — —	 200 µA 1.4 mA
Input low current for CPULL/DPULL (V_{in} = 0.4 V)	—	4 µA
Input high current for CPULL/DPULL (V_{in} = 2.4 V)	—	140 µA
Output low voltage (I_{OL} = 24 mA)	—	0.4 V
Output high voltage* (I_{OH} = 24 mA)	2.4 V	—
* When configured as standard outputs. Drivers configured as open-collector outputs are in the high-impedance state when logically high.		

Absolute max input voltage range .....–0.3 to 5 V

Power-on state for outputs .....High-impedance, pulled up or down (selectable)

Pull-up/down resistors
CPULL (for control lines) .....2.2 kΩ
DPULL (for data lines).....100 kΩ

Data transfers
(all devices except DAQCard).....Interrupt, DMA

Memory

NI AT-DIO-32HS.....16 S

NI DAQCard-6533 for PCMCIA .....16 S

NI PCI/PXI-6534.....64 MB, two 32 MB modules on each NI 6534

NI PCI/PXI-7030/6533.....16 S

NI PCI-DIO-32HS.....16 S

NI PXI-6533 .....16 S

Pattern I/O

Direction..... Input or output

Maximum sample rate (internally timed, for small transfers[1])..... 20 MHz

Minimum sample rate (internal clock rate) ..... 1 S/10 minutes

Change Detection

Change-detection resolution ..... 150 ns

Triggers

Start and Stop Triggers

Compatibility ..... TTL/CMOS

Trigger types ..... Rising or falling edge, or digital pattern

Pulse width for edge triggers (min)..... 10 ns

Pattern trigger detection capabilities ..... Detect pattern match or mismatch on user-selected data lines

Pattern trigger resolution..... 60 ns or one REQ period, depending on pattern I/O mode

RTSI Triggers (PCI, PXI, AT)

Trigger lines 7

Bus Interfaces

NI PCI-DIO-32HS/PXI-6533/ PCI-6534/PXI-6534/ AT-DIO-32HS type..... AT slave with dual DMA

NI DAQCard-6533 for PCMCIA type... PCMCIA slave

[1] Small transfer size is the size of the FIFO.

Power Requirement

+5 VDC (±5%) (with light output load)
NI PCI-DIO-32HS, NI PXI-6533 .....1.3 A
NI PCI-6534 and NI PXI-6534.....2.0 A
NI DAQCard-6533 for PCMCIA .....500 mA

Power Available at I/O Connector

NI PCI-DIO-32HS, NI PXI-6533,
NI AT-DIO-32HS,
NI PCI-6534, and NI PXI-6534.....+4.65 to +5.25 VDC at 1 A

NI DAQCard-6533 for PCMCIA .....+4.65 to +5.25 VDC at 250 mA

Physical

Dimensions, not including connectors

- NI DAQCard-6533 for PCMCIA ....8.6 by 5.3 cm (3.4 by 2.1 in.)
- NI AT-DIO-32HS/PCI-653*X*.....17.5 by 10.7 cm (6.9 by 4.2 in.)
- NI PXI-653*X*.....16.3 by 9.9 cm (6.4 by 3.9 in.)

I/O connector

- NI PCI-DIO-32HS, NI PXI-6533, NI AT-DIO-32HS, NI PCI-6534, and NI PXI-6534.....68-pin male SCSI-II type
- NI DAQCard-6533 for PCMCIA ....68-pin female PCMCIA connector

Environment

Operating temperature .....0 to 55 °C

Storage temperature .....–20 to 70 °C

Relative humidity .....5 to 90% noncondensing

Functional shock ..... MIL-T-28800 E Class 3 (per Section 4.5.5.4.1) Half-sine shock pulse, 11 ms duration, 30 g peak, 30 shocks per face

Operational random vibration (PXI only) ..... 5 to 500 Hz, 0.31 g_{rms}, 3 axes

Nonoperational random vibration (PXI only) ..... 5 to 500 Hz, 2.5 g_{rms}, 3 axes

Note Random vibration profiles were developed in accordance with MIL-T-28800E and MIL-STD-810E Method 514. Test levels exceed those recommended in MIL-STD-810E for Category 1 (Basic Transportation, Figures 514.4-1 through 514.4-3).

B

Using PXI with CompactPCI

You can use your NI PXI-653*X* as a plug-in device in a standard CompactPCI chassis, but then you cannot access PXI-specific functions, such as RTSI bus features detailed in the *PXI Specification*, rev. 1.0.

The CompactPCI specification permits vendors to develop sub-buses that coexist with the basic PCI interface on the CompactPCI bus. Compatible operation is not guaranteed between CompactPCI devices with different sub-buses nor between CompactPCI devices with sub-buses and PXI. The standard implementation for CompactPCI does not include these sub-buses. Your NI PXI-653*X* works in any standard CompactPCI chassis adhering to the *PICMG CompactPCI 2.0 R2.1* document.

PXI-specific features are implemented on the J2 connector of the CompactPCI bus. The following table lists the J2 pins used by your NI PXI-653*X*. Your PXI device is compatible with any CompactPCI chassis with a sub-bus that does not drive these lines. Even if the sub-bus is capable of driving these lines, the PXI device is still compatible as long as those pins on the sub-bus are disabled by default and not ever enabled.

Table B-1. J2 Pins Used by Your NI PXI-653*X*

PXI-653*X* Signal	PXI Pin Name	PXI J2 Pin Number
RTSI Trigger (0..6)	PXI Trigger (0..6)	B16, A16, A17, A18, B18, C18, E18
Reserved	PXI Star	D17
RTSI Clock	PXI Trigger (7)	E16
Reserved	LBR (7, 8, 10, 11, 12)	A3, C3, E3, A2, B2

C

Connecting Signals with Accessories

This appendix describes how to connect signals to your NI 653*X*. Use the first part of the appendix to acquaint yourself with the device control signals. Then go to appropriate pinout diagrams (68- or 50-pin), which display the layout of pin locations.

Control Signals

Use the four control signals to regulate/control the timing of your data transfer when using the handshaking and pattern I/O modes. The direction and function of each signal varies, depending on the mode of operation, as shown in Table C-1.

Table C-1. Control Signals for Handshaking I/O and Pattern I/O

Signal Name	Handshaking I/O		Pattern I/O	
	Direction	**Function**	**Direction**	**Function**
REQ<1..2>	Input	Request—Indicates that the peripheral device is ready	Input or Output	Request—Clocks the data transfer
ACK<1..2> or STARTTRIG<1..2>	Output	Acknowledge—Indicates the NI 653*X* is ready	Input	Start trigger
STOPTRIG<1..2>	N/A	N/A	Input	Stop trigger
PCLK<1..2>	Input or Output	Peripheral clock	N/A	N/A

Making 68-Pin Signal Connections

Caution Do *not* make connections that exceed any of the maximum input or output ratings on the NI 653*X*, listed in Appendix A, *Specifications*. This includes connecting any power signals to ground and vice versa. Doing so may damage your device and your computer. NI is *not* liable for any damages resulting from these types of signal connections.

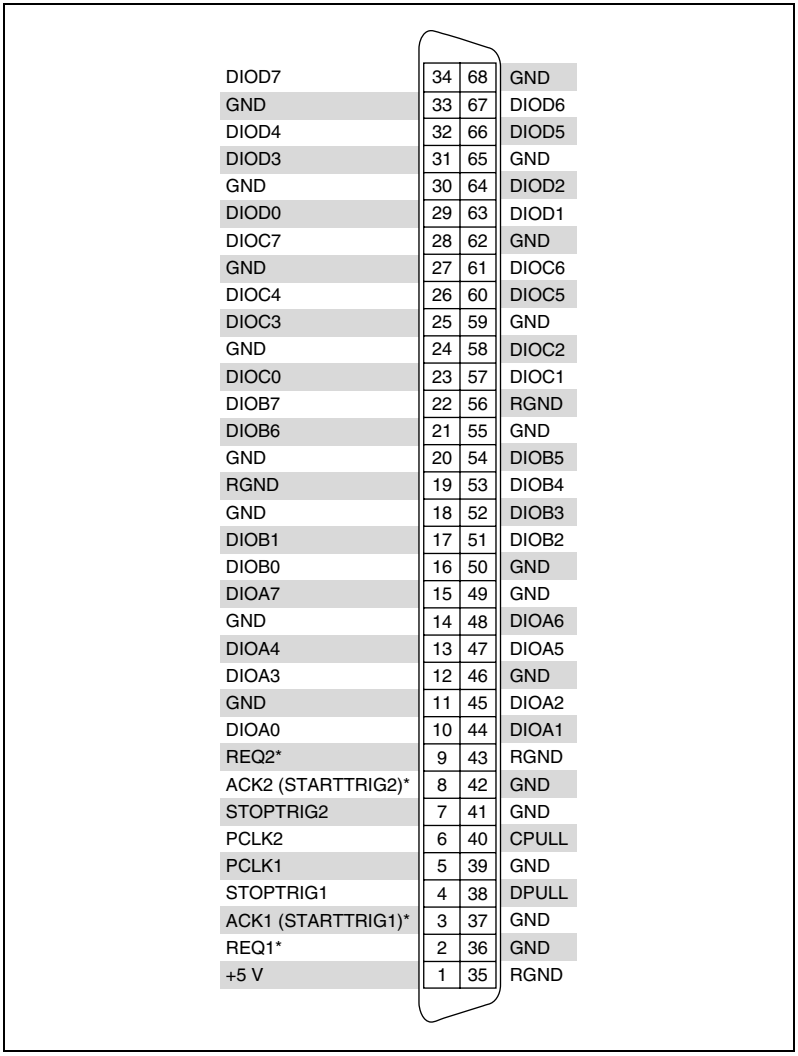


Figure C-1. NI 653*X* I/O Connector 68-Pin Assignments

Note In Figure C-1, the * indicates that you can reverse the pin assignments of the ACK1 (STARTTIG1) and REQ1 pins, or the ACK2 (STARTTIG2) and REQ2 pins. To do this, set the `ACK-REQ Exchange` attribute to ON in the DIO Parameter VI in LabVIEW or in `set_DAQ_Device_Info` in NI-DAQ. This allows you to perform handshaking I/O between two NI 653*X* devices using an SH-68-68-D1 cable.

Use Table C-2 to find the accessories designed for connecting signals to your NI 653*X*.

Table C-2. 68-Pin Accessories

Device	Shielded Cable	Ribbon Cable	Cable Adapter
PCI/PXI/AT/ Compact PCI	SHC68-68-D1—female 68-pin SCXI connectors on both ends of the cable	N/A	N/A
NI DAQCard-6533 for PCMCIA	PSHR68-68-D1 and PSHR68-68M	PR68-68F	N/A

Signal Descriptions

Use Table C-3 to find the function for each signal, which is based on the mode and protocol you are using. All the signals on the NI 653*X* are referenced to the GND lines.

Table C-3. Signal Descriptions

Pins	Signal Name	Signal Type	Signal Description Based on Mode Used
2, 9	REQ<1..2>	Control	Group 1 and group 2 request lines **Handshaking I/O**—Request. A control line that indicates whether the peripheral device is ready to transfer data. **Pattern I/O**—REQ carries timing pulses either to or from the peripheral device. These strobe signals are comparable to the CONVERT* or UPDATE* signals of an analog DAQ device. **Unstrobed I/O**—Option to use REQ<1..2> as extra, general-purpose input lines (IN<3..4>).
3, 8	ACK<1..2> STARTTRIG <1..2>	Control	Group 1 and group 2 acknowledge lines **Handshaking I/O**—Acknowledge, a control line that indicates whether the NI 653*X* is ready to transfer data. **Pattern I/O**—Used as a start trigger (STARTTRIG<1..2>) line. You can start pattern I/O operations upon the rising or falling edge of a signal on these lines. **Unstrobed I/O**—Option to use the ACK<1..2> lines as extra, general-purpose output lines (OUT<3..4>).
4, 7	STOPTRIG <1..2>	Control	Group 1 and group 2 stop triggers **Handshaking I/O**—Not used. **Pattern I/O**—Used in trigger operations as stop trigger. You can end pattern I/O operations upon the rising or falling edge on these lines. **Unstrobed I/O**—Option to use the STOPTRIG<1..2> lines as extra, general-purpose input lines (IN<1..2>).
5–6	PCLK<1..2>	Control	Group 1 and group 2 peripheral clock lines **Handshaking I/O (Burst Mode)**—The only handshaking mode that utilizes these signals. By default, PCLK is an output during an input operation and an input during an output operation. PCLK direction is programmable. **Pattern I/O**—Not used. **Unstrobed I/O**—Option to use the PCLK<1..2> lines as extra, general-purpose output lines (OUT<1..2>).
10, 44–45, 12–13, 47–48, 15	DIOA<0..7>	Data	Port A bidirectional data lines Port A is referred to as port number 0 in software. DIOA7 is the most significant bit (MSB); DIOA0 is the least significant bit (LSB).
16–17, 21–22, 51–54	DIOB<0..7>	Data	Port B bidirectional data lines Port B is referred to as port number 1 in software. DIOB7 is the MSB; DIOB0 is the LSB.

Table C-3. Signal Descriptions (Continued)

Pins	Signal Name	Signal Type	Signal Description Based on Mode Used
23, 57–58, 25–26, 60–61, 28	DIOC<0..7>	Data	Port C bidirectional data lines Port C is referred to as port number 2 in software. DIOC7 is the MSB; DIOC0 is the LSB.
29, 63–64, 31–32, 66–67, 34	DIOD<0..7>	Data	Port D bidirectional data lines Port D is referred to as port number 3 in software. DIOD7 is the MSB; DIOD0 is the LSB.
40	CPULL	Bias Selection	Control pull-up/pull-down selection Input signal that selects whether the NI 653*X* pulls the timing and handshaking control lines (REQ, ACK, PCLK, and STOPTRIG) up or down when the lines are not driven. If you connect CPULL to +5 V on the external terminal connector, the NI 653*X* pulls the control lines up. If you connect CPULL to GND or leave CPULL unconnected, the NI 653*X* pulls the control lines down. Refer to power on state the *Power-On State* section of Appendix D, *Hardware Considerations*, for more information.
38	DPULL	Bias Selection	Data pull-up/pull-down selection Input signal that selects whether the NI 653*X* pulls the data lines (DIOA, DIOB, DIOC, and DIOD) up or down when the lines are not driven. If you connect DPULL to +5 V on the external terminal connector, the NI 653*X* pulls the data lines up. If you connect DPULL to GND or leave DPULL unconnected, the NI 653*X* pulls the data lines down. Refer to power on state the *Power-On State* section of Appendix D, *Hardware Considerations*, for more information.
1	+5 V	Power	5 V output Line that provides a maximum of 1 A of power. This line is protected by an onboard fuse that shuts off power when there is too much current and automatically resets itself after current returns to normal.
11, 14, 18, 20, 24, 27, 30, 36–37, 39, 41–42, 46, 49–50, 55, 59, 62, 65, 68	GND	Power	Ground These lines are the ground reference for all other signals.
19, 35, 43, 56	RGND	Power	Reserved ground These lines offer additional ground pins. If you are using an R6868 ribbon cable for example, these lines can be used as additional ground references. If you are using an SH68-68-D1, however, these signals are not connected.

Making 50-Pin Signal Connections

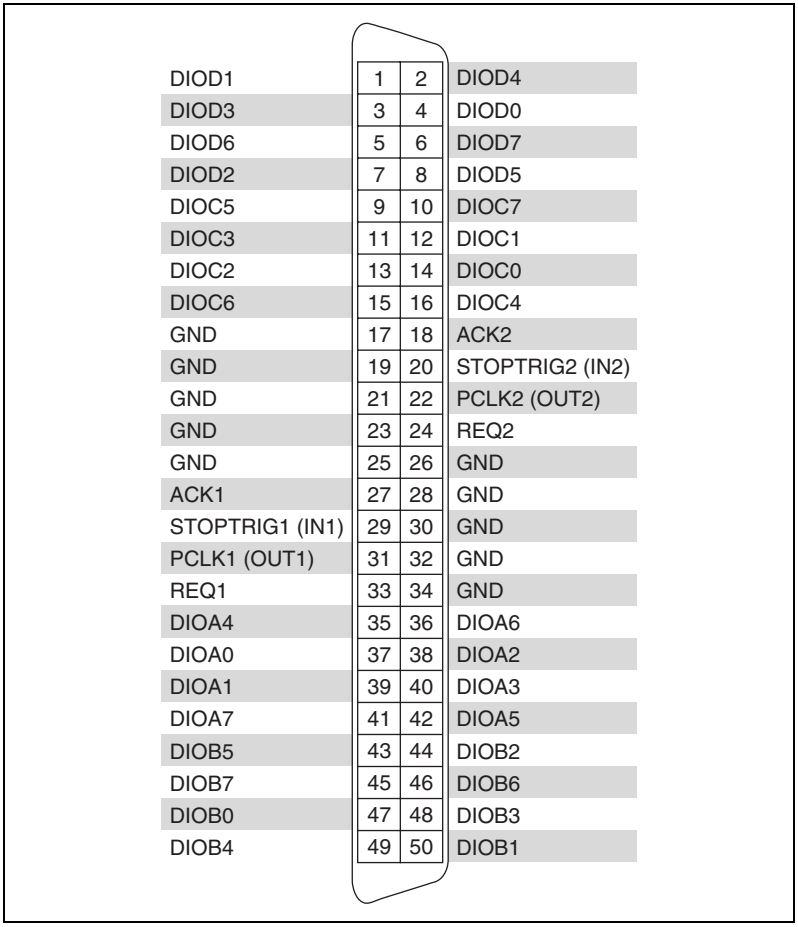


Figure C-2. 68-to-50-Pin Adapter Pin Assignments

Use Table C-4 to find the accessories designed to connect to your NI 653*X*.

Table C-4. 50-Pin Accessories

Device	Shielded Cable	Ribbon Cable	Cable Adapter
NI PCI-6534 NI PCI-DIO-32HS NI AT-DIO-32HS	SH68-68-D1	R6868	R6850-D1 (Converts 68 pin to 50 pin)
NI PXI-6534 NI PXI-6533	SH68-68-D1	R6868	R6850-D1 (Converts 68 pin to 50 pin)
NI DAQCard-6533 for PCMCIA	PSHR68-68M	N/A	R6850-D1 (Converts 68 pin to 50 pin)

To use your NI 653*X* with cables, signal conditioning modules, and other accessories that require an AT-DIO-32F pinout, use the R6850-D1, an optional 68-to-50-pin device adapter. Using a PSHR68-68M shielded cable, you can also connect the adapter to an NI DAQCard 6533.

The female side of the R6850-D1 adapter connects directly to the NI 653*X* or PSHR68-68M cable. The male side of the adapter provides the pin assignments shown in Figure C-2. The 50-pin adapter has no +5 V, CPULL, or DPULL pins.

Optional Equipment for Connecting Signals

NI offers a variety of accessories to extend your NI 653*X* capabilities, including:

- Cables and cable assemblies, shielded and ribbon
- Connector blocks, shielded and unshielded 50- and 68-pin screw terminals
- RTSI bus cables for AT and PCI devices
- SCXI modules and accessories that can acquire up to 3072 channels, and that can isolate, amplify, excite, and multiplex signals for relays and analog output
- Low channel-count signal conditioning modules, devices, and accessories, including conditioning for strain gauges and RTDs, simultaneous sample and hold, relays, and optical isolation

For more information about these products, refer to the NI catalog, ni.com, or call the office nearest you.

D

Hardware Considerations

This appendix covers several hardware considerations for your NI 653*X*. As an advancbed user, you can use these sections to understand how your NI 653*X* hardware works.

Block Diagrams

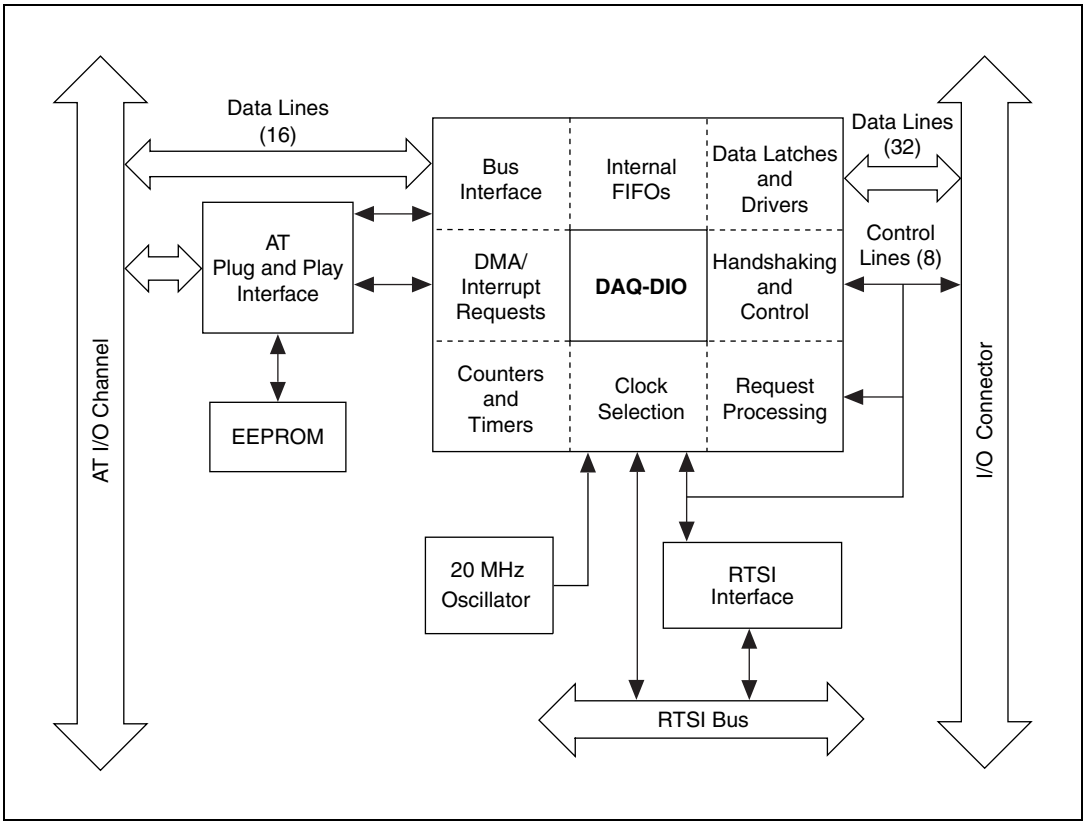


Figure D-1. NI AT-DIO-32HS Block Diagram

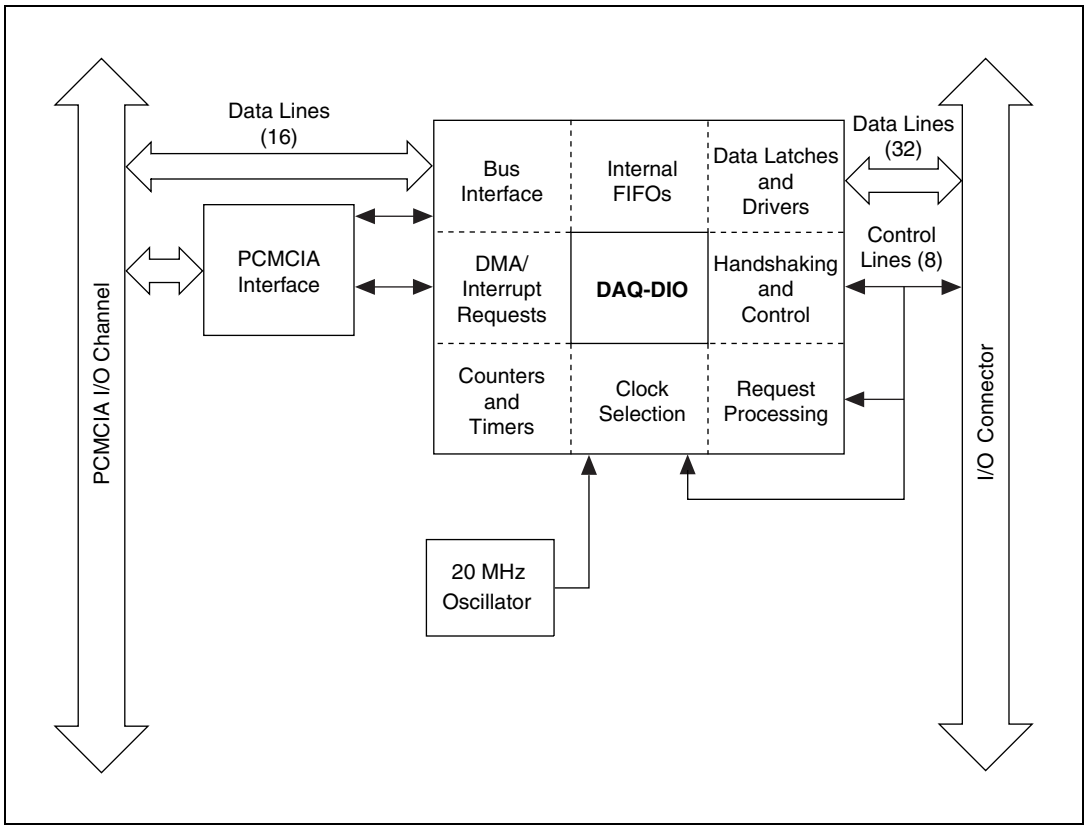


Figure D-2. NI DAQCard-6533 for PCMCIA Block Diagram

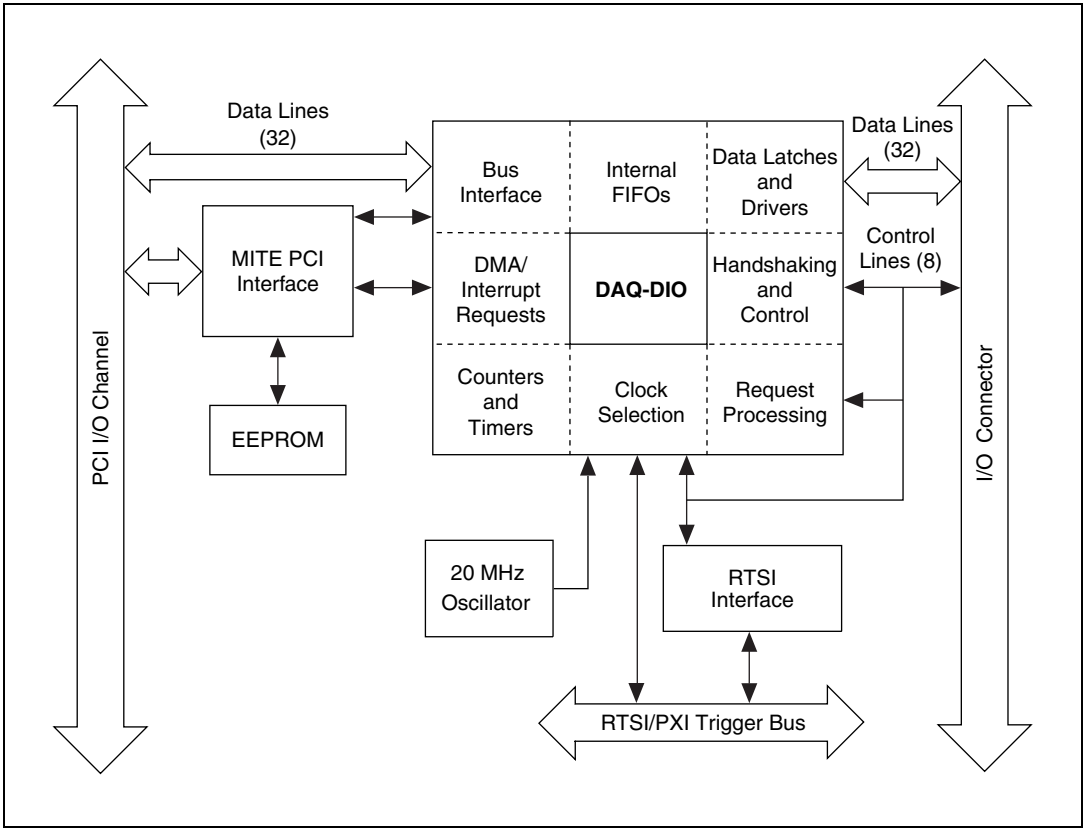


Figure D-3. NI PCI-DIO-32HS, NI PCI/PXI-7030/6533, and NI PXI-6533 Block Diagram

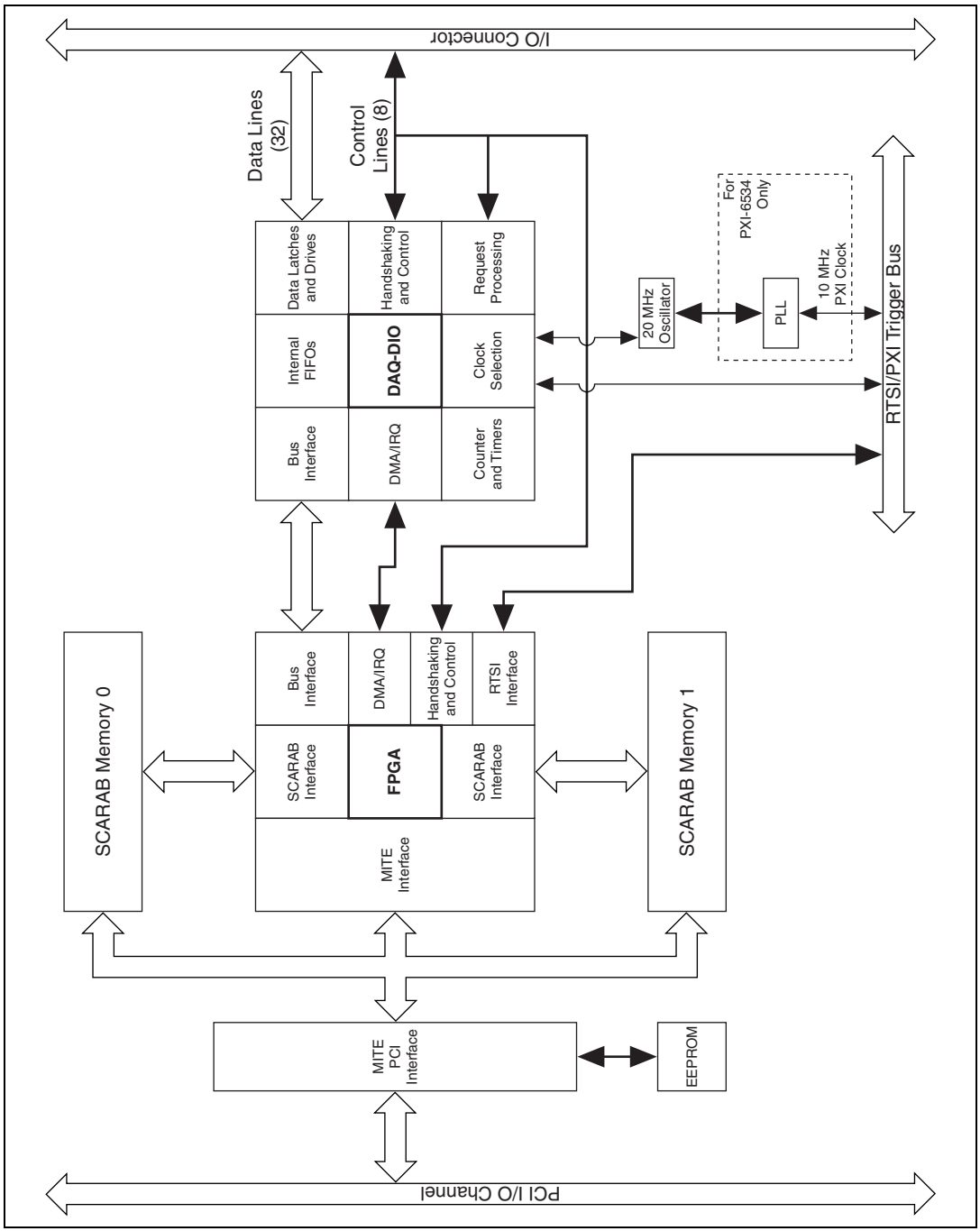


Figure D-4. NI PCI/PXI-6534 Block Diagram

Power-On State

When the computer is first powered on, all lines are configured for input and are in the high-impedance state. By default, the data and control lines in the NI 653*X* are pulled down, even if the CPULL and DPULL are disconnected. You can select the biasing of control and data signals using the CPULL and DPULL lines:

- CPULL line—For control lines, it is a user-configurable 2.2 kΩ internal resistor. You can connect the line to +5 VDC (*pull up*) or connect the line to ground (*pull down*).
- DPULL line—For data lines, it is a user-configurable 100 kΩ internal resistor. You can connect the line to +5 VDC (*pull up*) or connect the line to ground (*pull down*).

Caution Do *not* connect CPULL, DPULL, or any other line directly to an external power supply while the NI 653*X* is powered off. This action may prevent your computer from booting.

For example, if you are using active-low handshaking signals, you can connect the CPULL line to +5 V to place the handshaking lines in the high, inactive state at power up.

Power Connections

The +5 V pin on the I/O connector supplies power from the computer power supply through a self-resetting fuse. The fuse resets automatically within a few seconds after removal of an overcurrent condition. The power pin is referenced to the GND pins and can supply power to external digital circuitry. The power ratings for the +5 V pin for the various NI 653*X* devices are shown in Table D-1.

Table D-1. NI 653*X* Power Ratings

Device	Power Rating
NI PCI-DIO-32HS	+4.65 to +5.25 VDC at 1 A
NI PXI-6533	
NI AT-DIO-32HS	
NI DAQCard-6533 for PCMCIA	+4.65 to +5.25 VDC at 250 mA

Table D-1. NI 653*X* Power Ratings (Continued)

Device	Power Rating
NI PCI-6534	+4.65 to +5.25 VDC at 1 A
NI PXI-6534	+4.65 to 5.25 VDC at 250 mA

You can connect the +5 V pin to the CPULL and DPULL pins to control the bias of the NI 653*X* control and data lines, as described in the *Power-On State* section.

Caution Do *not* connect the +5 V power pin directly to the GND, RGND, or any output pin of the NI 653*X* or any voltage source or output pin on another device. Doing so can damage the device and the computer. NI is *not* liable for damage resulting from such a connection.

Selecting and Terminating Cables

It is important to select an appropriate cable and to properly terminate it to avoid undershoots, overshoots, and reflections. The SH6868-D1 is a twisted-pair cable. Each signal conductor is twisted with a ground conductor that establishes a low-inductance uniform transmission line. For more information about this cable and other accessories, refer to Appendix C, *Connecting Signals with Accessories*.

Tip Cables that do not meet the above requirements, such as ordinary ribbon cables, should only be used for short distances and for applications where signal reflections are not a concern, because they cannot be properly terminated.

Without termination, any sharp transition in a signal can lead to overshooting above 5 V, undershooting below 0 V, or false edges due to reflections (“ringing”). Proper termination is recommended for low-speed transfers as well as high-speed devices like your NI 653*X*. It is crucial to properly terminate the cable with a high-speed device because there are more transitions per unit time, sharper signal edges, and input lines that might respond to false edges resulting from reflection.

Using the Schottky-Diode Termination Scheme

You can terminate a cable that acts as a uniform transmission line in several ways. If your NI 653*X* is driving a cable, use the following termination scheme: connect two Schottky diodes to each line, one to +5 VDC and the other to ground. This termination clamps any overshoot or undershoot that occurs. The +5 V and ground connections should be low-impedance connections. For example, if you make your +5 V connection through a long wire, back to the +5 V pin of the NI 653*X*, add a capacitor to your termination circuit to stabilize the +5 V connection near the Schottky diodes.

One suitable Schottky diode is the 1N5711, available from several manufacturers. For more specialized use, you may be able to find diodes packaged in higher densities appropriate to your application. For example, the Central Semiconductor CMPSH-35 contains two diodes, suitable for terminating one line. The California Micro Devices PDN001 contains 32 diodes, suitable for terminating 16 lines.

You do not need to add diodes to terminate the input signals. The NI 653*X* contains onboard Schottky diode termination. Figure D-5 illustrates transmission line terminations.

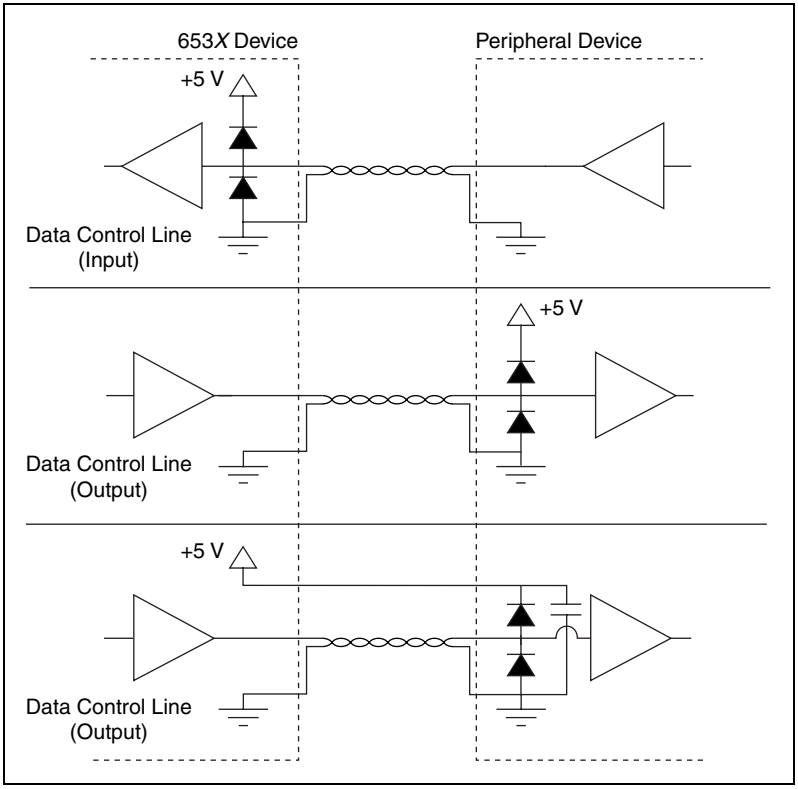


Figure D-5. Transmission Line Terminations

Note Run the signal lines through special metal conduits to protect them from magnetic fields caused by electric motors, welding equipment, breakers, or transformers.

If you are using the Schottky diode termination scheme, you do not need to know the exact input, output, or cable impedances. NI does not specify the source or input impedance or slew rate of the NI 653*X* or the characteristic impedance of the SH6868-D1 cable. However, the following information might be helpful:

- I/O buffers—The NI 653*X* uses 24 mA rate-controlled TTL-level CMOS drivers that provide a low output impedance of 10 Ω (typical) and a high input impedance limited by the onboard bias resistors to 2.2 kΩ for control lines and 100 kΩ for data lines.
- Slew rate—The rate-controlled outputs have been deliberately slowed to reduce termination difficulties. Rise or fall time depends on load, but 2.75 to 4.5 ns is typical.

There is no specific cutoff frequency at which termination becomes necessary.

Note A purely resistive termination scheme is not recommended because of the current drawn by the termination resistors. For example, a 90 Ω terminating resistor works well to dampen reflections, but sinks 27 mA even at 2.4 V. NI 653*X* devices are rated to sink only 24 mA.

Follow these signal conditioning recommendations for optimum use:

- Separate NI 653*X* signal lines from high-current or high-voltage lines. These lines are capable of inducing currents in or voltages on the NI 653*X* signal lines if they run in parallel paths at a close distance. To reduce the magnetic coupling between lines, separate them by a reasonable distance if they run in parallel, or run the lines at right angles to each other.
- Do *not* run signal lines through conduits that also contain power lines.

How Much Current Can I Sink or Source?

Make sure the sink current does not exceed 24 mA at 0.4 V to guarantee that TTL low voltage specifications are met. The sink current is the amount of current that flows into the NI 653*X* when it asserts a TTL low signal (often denoted by I_{OUT} or I_{OL} in an Output Low Voltage specification).

Also, it is important to make sure the source current does not exceed –24 mA at 2.4 V to guarantee TTL high voltage specifications. The source current is the amount of current that flows out of the NI 653*X* when it asserts a TTL high signal (often denoted in an Output High Voltage specification by I_{OUT} or I_{OH}).

Note Most NI digital I/O products have similar source and sink currents.

Table D-2. Sink and Source Current for the NI 653*X*

Sink Current	Source Current
24 mA at 0.4 V	–24 mA at 2.4 V

Note If you are using the NI DAQCard-6533 for PCMCIA, your PCMCIA socket may not provide sufficient power to drive all outputs at 24 mA.

RTSI and PXI Trigger Bus Interfaces

You can use the seven bidirectional RTSI lines on the RTSI bus to share signals between devices. Use the RTSI bus interface to synchronize multiple cards or change control signals with multiple devices.

The NI PCI-6534, NI PCI-DIO-32HS and NI AT-DIO-32HS each contain a RTSI connector and an interface to the National Instruments RTSI bus. The RTSI bus provides seven trigger lines and a system clock line. All NI AT- and PCI-bus devices that have RTSI bus connectors can be cabled together inside a computer to share these signals.

The NI PXI-653*X* uses pins on the PXI J2 connector to connect the RTSI bus to the PXI trigger bus as defined in the *PXI Specification*, *rev. 1.0*. All NI PXI modules that provide a connection to these pins can be connected with software. This feature is available only when the NI PXI-653*X* is used in a PXI-compatible chassis. It is not supported in CompactPCI chassis.

Board, RTSI, and PXI Bus Clocks

The NI 653*X* requires a clock to run the handshaking logic and to generate sampling intervals for pattern I/O. The frequency timebase must be 20 MHz.

The NI 653*X* can use its internal 20 MHz clock source, or you can provide a clock from another 20 MHz device over the RTSI bus. When using its internal 20 MHz clock, the NI 653*X* can also drive its internal timebase onto the bus and to another device that uses a 20 MHz clock.

Whether internal or external, the 20 MHz clock serves as the primary frequency source for the NI 653*X*. By default, the NI 653*X* uses an internal clock. You can programmatically change the source of the clock through software.

- NI PXI-653*X*—The NI PXI-653*X* uses PXI trigger line 7 as the RTSI clock line.

Phase-Locked Loop Circuit (NI PXI-6534 Only)

A phase-locked loop (PLL) circuit accomplishes the synchronization of multiple NI PXI-6534 devices or other PXI devices which support PLL synchronization by allowing these devices to all lock to the same reference clock present on the PXI backplane. This circuit allows you to trigger input or output operations on different devices and ensures that samples occur at the same time.

The PLL circuitry consists of a voltage-controlled crystal oscillator (VCXO) with a tuning range of ±50 ppm. The VCXO generates the 20 MHz master clock used onboard the NI PXI-6534.

The PLL locks to the 10 MHz system clock (PXI_CLK10) on the PXI backplane bus. A phase comparator running at 1 MHz compares the PXI bus and VCXO clock. The loop filter then processes the error signal and outputs a control voltage for the VCXO. Refer to Figure D-6 for a block diagram of the PLL circuit on the NI PXI-6534.

Note This feature is *not* available on the NI PCI-6534.

The PLL circuit is automatically enabled when the NI PXI-6534 is powered on. No configuration steps are required in order to utilize PLL synchronization.

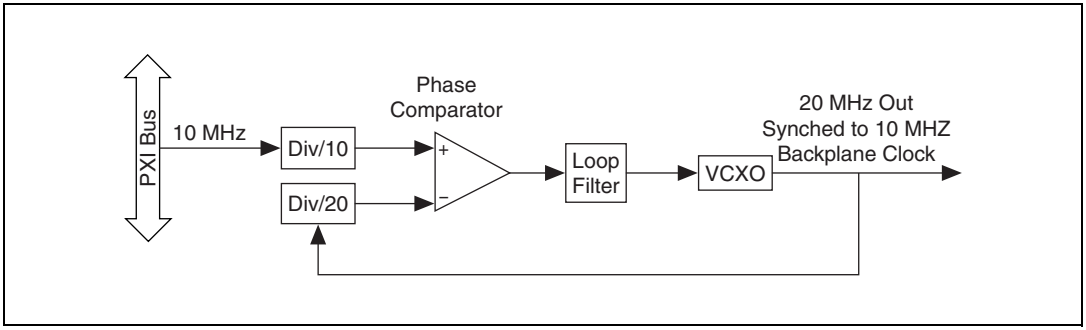


Figure D-6. PLL Circuit Block Diagram

RTSI and PXI Bus Triggers

The seven RTSI lines on the RTSI bus provide a flexible interconnection scheme for any device sharing the RTSI or PXI trigger bus. Any control signal on the device can connect to a RTSI or PXI trigger bus line. You can drive output control signals onto the bus and receive input control signals from the bus. Figure D-7 shows the signal connection scheme.

Note If you configure a signal to be received from the RTSI bus, do not attach it to an external source. Also, do not configure the NI 653*X* to generate that signal internally.

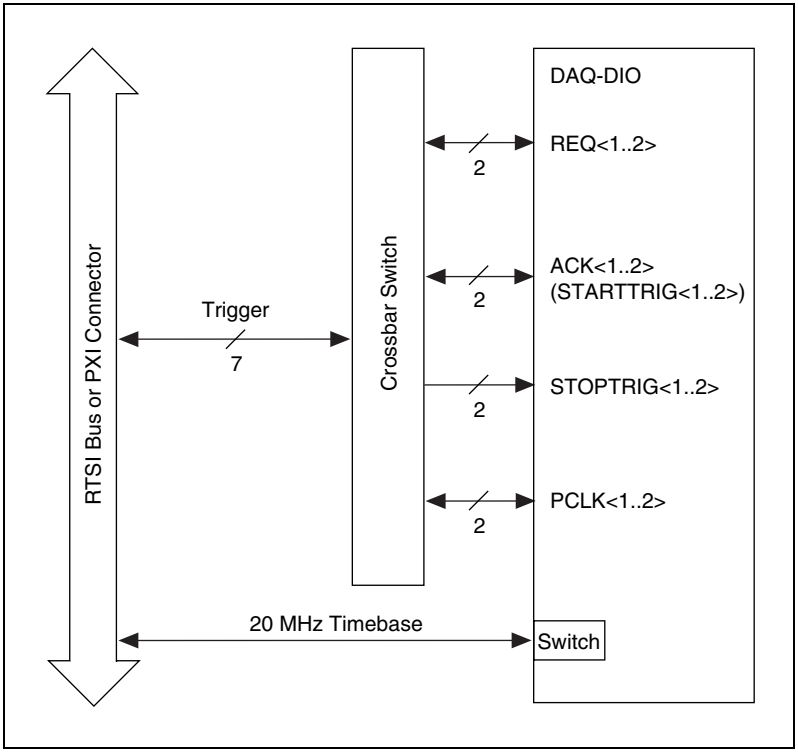


Figure D-7. RTSI Bus Signal Connection

E

Optimizing Your Transfer Rates

Use this appendix to determine the maximum transfer rate for your device, optimize transfer rates, and to see example benchmark results.

Determining the Maximum Transfer Rates

The maximum sustainable transfer rate an NI 653*X* can achieve depends on the minimum available bus bandwidth and is based on your computer system. The maximum sustainable transfer rate also depends on the number of other devices generating bus cycles, your operating system, and your application software. The maximum sustainable transfer rate is always lower than the peak transfer rate.

The average bus bandwidth requirements differ between specific NI 653*X* devices. Here, the NI 653*X* devices are listed in order of their average bus bandwidth requirements, from highest to lowest:

- NI PCI/PXI-6534
- NI PCI/PXI-6533
- NI AT-DIO-32HS
- NI DAQCard-6533 for PCMCIA

♦ NI 6534

With the NI 6534, if the data you are acquiring/generating fits in the onboard memory, the transfer rate is not limited by the bus bandwidth, only by the maximum transfer rate based on the protocol used. These rates are listed in Table E-1. The peak transfer rates are based on a system with a 1-meter cable.

Table E-1. Peak Transfer Rates Based on Mode and Protocol Used

Mode/Protocol	Peak Rate (MS/s)
Handshaking 8255	4
Handshaking Level-ACK	2.86
Handshaking Leading-Edge Pulse	2.86

Table E-1. Peak Transfer Rates Based on Mode and Protocol Used (Continued)

Mode/Protocol	Peak Rate (MS/s)
Handshaking Long Pulse	2.86
Handshaking Trailing-Edge Pulse	1.67
Handshaking Burst	20
Pattern I/O	20

Obtaining the Fastest Transfer Rates

To achieve the highest transfer rates possible, consider the following:

- Burst mode is the fastest handshaking protocol. You can further increase speed by using short cables.
- Finite transfer is faster than continuous transfer.
- Minimize the number of other I/O devices active in the system. Your system bus should be as free as possible from unrelated activity.
- Use the NI 6534, which has onboard memory. If you are using an NI 6533, you can connect it to an external FIFO using the burst handshaking protocol and clock data out of the FIFO to the peripheral device.
- Output looping from the NI 6534 onboard memory is faster than regenerating output from the NI 6533.
- DMA transfers are faster than interrupt-driven transfers, especially for pattern I/O. Refer to Table E-2 to determine whether your device supports DMA transfers. If DMA transfers are available, the software uses DMA transfers by default.

Table E-2. Devices That Support Direct-Memory Access (DMA) Transfers

Device	Direct-Memory Access
NI AT-DIO-32HS	Supported if system DMA resources available. If you use two DMA channels, data transfer is faster.
NI DAQCard-6533 for PCMCIA	Not supported
NI PCI-DIO-32HS NI PCI-6534	Supported
NI PXI-6533 NI PXI-6534	Supported if device is in a peripheral slot that allows bus arbitration (bus mastering). Otherwise, use software to select interrupt-driven transfers. PXI chassis have bus arbitration for all slots.

Interpreting Benchmark Results

Use benchmark results to get a general idea of what transfer rates to expect for an application. Since these results are system dependent, they are not to be used as specifications. View the latest results on our Web site, `ni.com`.

Benchmark results are in megasamples per second (MS/s) for sample sizes of one, two, and four bytes. For example, if you are performing an eight-bit operation, then sample size is one byte. Sixteen bits is two bytes and 32 bits is four bytes.

To convert from MS/s to MB/s, use the following formula:

$$\frac{MS}{s} \times \frac{sample\ size\ (B)}{1S} = \frac{MB}{s}$$

where *sample size* can be one, two, or four bytes.

For example, 10 MS/s, where each sample is 16 bits (two bytes):

$$\frac{10MS}{s} \times \frac{2\ bytes}{1S} = \frac{20MB}{s}$$

The following applications were tested:

- Finite (pattern I/O and burst protocol)—One buffer of data is transferred one time.

- Continuous Retransmit Output (pattern I/O and burst protocol)—One buffer of data is loaded into memory one time, and output over and over again.
- Continuous Input (pattern I/O and burst protocol)—New data is continually input into the application software.

NI AT-DIO-32HS

The following benchmarks are results using a Dell Dimension XPS, 600 MHz, PIII, and Windows 98 SE.

Table E-3. NI AT-DIO-32HS Benchmark Results

Mode		Benchmark Rate (MS/s)		
		8-Bit Samples	**16-Bit Samples**	**32-Bit Samples**
Pattern I/O–Single Shot	Input	1.67	.87	.83
	Output	1.47	.74	.38
Pattern I/O–Continuous	Input	1.67	.80	.31
Pattern I/O–Continuous Retransmit	Output	1.43	.67	.39
Burst Protocol–Continuous	Input	1.74	.87	.43
Burst Protocol–Continuous Retransmit	Output	1.51	.76	.37

NI PCI-DIO-32HS (NI PCI-6533)

The following benchmarks are results using a Dell Optiplex GX150 with a 1 GHz processor, 256 MB RAM, Microsoft Windows 2000, LabVIEW 6.0, and NI-DAQ 6.9.2.

Table E-4. NI PCI-DIO-32HS Benchmark Results

Mode	Buffer Size	Benchmark Rate (MS/s)		
		8-Bit Samples	16-Bit Samples	32-Bit Samples
Pattern Input–Finite	32 MB	10	5	5
	64 MB	10	5	5
Pattern Output–Finite	32 MB	5	2.22	2.22
	64 MB	4	2.22	2.22
Pattern Input–Continuous	1 GB	2.5	1.43	1.43
Pattern Output–Continuous	1 GB	4	2	2
Pattern Output–Continuous Regenerated	1 GB	3.33	2	2
Burst Protocol Input–Finite	32 MB	19.9	19.5	19.1
	64 MB	19.9	19.5	19.1
Burst Protocol Output–Finite	32 MB	19.6	18.7	16.6
	64 MB	19.6	18.7	16.6
Burst Protocol Input–Continuous	1 GB	20	19.7	17.3
Burst Protocol Output–Continuous	1 GB	19.9	18.6	13

NI PXI-6533

The following benchmarks are results using an NI PXI-8170 controller with an 850 MHz processor, 256 MB RAM, Windows 2000, LabVIEW 6.0, and NI-DAQ 6.9.2.

Table E-5. NI PXI-6533 Benchmark Results

Mode	Buffer Size	Benchmark Rate (MS/s)		
		8-Bit Samples	16-Bit Samples	32-Bit Samples
Pattern Input–Finite	32 MB	10	5	5
	64 MB	10	5	5
Pattern Output–Finite	32 MB	5	2.857	2.857
	64 MB	5	2.5	2.5
Pattern Input–Continuous	1 GB	2.5	1.43	1.43
Pattern Output–Continuous	1 GB	5	2.5	2.5
Pattern Output–Continuous Regenerated	1 GB	5	2.5	2.5
Burst Protocol Input–Finite	32 MB	19.9	19.5	19.1
	64 MB	19.9	19.5	19.1
Burst Protocol Output–Finite	32 MB	19.6	18.7	16.5
	64 MB	19.6	18.7	16.5
Burst Protocol Input–Continuous	1 GB	19.9	19.6	13.2
Burst Protocol Output–Continuous	1 GB	19.7	17.8	9

NI DAQCard-6533 for PCMCIA

The following benchmarks are results using an NI PXI-8170, 450 MHz PIII, and Windows 98.

Table E-6. NI DAQCard-6533 for PCMCIA Benchmark Results

Mode		Benchmark Rate (MS/s)		
		8-Bit Samples	16-Bit Samples	32-Bit Samples
Pattern I/O–Single Shot	Input	0.12	.11	.10
	Output	0.12	.12	.10
Pattern I/O–Continuous	Input	0.12	.11	.10
Pattern I/O–Continuous Retransmit	Output	0.12	.12	.10
Burst Protocol–Continuous	Input	0.24	.24	.19
Burst Protocol–Continuous Retransmit	Output	0.24	.24	.19

NI PCI-6534

The following benchmarks are results using a Dell Optiplex GX150 with a 1 GHz processor, 256 MB RAM, Microsoft Windows 2000, LabVIEW 6.0, and NI-DAQ 6.9.2.

Table E-7. NI PCI-6534 Benchmark Results

Mode	Buffer Size	Benchmark Rate (MS/s)		
		8-Bit Samples	16-Bit Samples	32-Bit Samples
Pattern Input–Finite	32 MB	20	20	20
	64 MB	20	20	20
Pattern Output–Finite	32 MB	20	20	20
Pattern Input–Continuous	1 GB	20	10	5
Pattern Output–Continuous	1 GB	20	10	5
Pattern Output–Continuous Looping from Onboard Memory	≤32 MB	20	20	20
Burst Protocol Input–Finite	32 MB	19.9	19.8	19.7
	64 MB	19.9	19.8	19.7
Burst Protocol Output–Finite	32 MB	20	19.9	17.9
Burst Protocol Input–Continuous	1 GB	20	20	18.1
Burst Protocol Output–Continuous	1 GB	20	19.8	13

NI PXI-6534

The following benchmarks are results using an NI PXI-8170 controller with an 850 MHz processor, 256 MB RAM, Windows 2000, LabVIEW 6.0, and NI-DAQ 6.9.2.

Table E-8. NI PXI-6534 Benchmark Results

Mode	Buffer Size	Benchmark Rate (MS/s)		
		8-Bit Samples	16-Bit Samples	32-Bit Samples
Pattern Input–Finite	32 MB	20	20	20
	64 MB	20	20	20
Pattern Output–Finite	32 MB	20	20	20
Pattern Input–Continuous	1 GB	20	20	10
Pattern Output–Continuous	1 GB	20	10	6.67
Pattern Output–Continuous Looping from Onboard Memory	≤32 MB	20	20	20
Burst Protocol Input–Finite	32 MB	19.9	19.5	19.1
	64 MB	19.9	19.5	19.1
Burst Protocol Output–Finite	32 MB	19.6	18.7	16.5
	64 MB	19.6	18.7	16.5
Burst Protocol Input–Continuous	1 GB	19.9	19.6	13.2
Burst Protocol Output–Continuous	1 GB	19.7	17.8	9

NI PCI-7030/6533 with LabVIEW RT

The following benchmarks are results using a 133 MHz AMD 486DX5 class processor and the real-time operating system running on LabVIEW RT.

Table E-9. NI PCI-7030/6533 Benchmark Results

Mode		Benchmark Rate (MS/s)		
		8-Bit Samples	16-Bit Samples	32-Bit Samples
Pattern I/O–Single Shot	Input	1.82	.95	.49
	Output	1.82	.91	.47
Pattern I/O–Continuous	Input	1.67	.87	.48
Pattern I/O–Continuous Retransmit	Output	1.25	.65	.48
Burst Protocol–Continuous	Input	2.04	1.02	.49
	Output	1.99	.95	.48

NI PXI-6533 with LabVIEW RT

The following benchmarks are results using an NI PXI-8170, 450 MHz PIII, and the real-time operating system running on LabVIEW RT.

Table E-10. NI PCI-7030/6533 Benchmark Results

Mode		Benchmark Rate (MS/s)		
		8-Bit Samples	16-Bit Samples	32-Bit Samples
Pattern I/O–Single Shot	Input	10	10	6.67
	Output	10	6.67	4
Pattern I/O–Continuous	Input	2.50	1.54	1.43
	Output	2	1	1

Table E-10. NI PCI-7030/6533 Benchmark Results (Continued)

Mode		Benchmark Rate (MS/s)		
		8-Bit Samples	**16-Bit Samples**	**32-Bit Samples**
Pattern I/O–Continuous Retransmit	Output	2.50	1.25	1.25
Burst Protocol–Continuous	Input	19.98	19.97	19.97
	Output	19.97	17.72	8.60

F

Technical Support and Professional Services

Visit the following sections of the National Instruments Web site at ni.com for technical support and professional services:

- **Support**—Online technical support resources at ni.com/support include the following:
  - **Self-Help Resources**—For answers and solutions, visit the award-winning National Instruments Web site for software drivers and updates, a searchable KnowledgeBase, product manuals, step-by-step troubleshooting wizards, thousands of example programs, tutorials, application notes, instrument drivers, and so on.
  - **Free Technical Support**—All registered users receive free Basic Service, which includes access to hundreds of Application Engineers worldwide in the NI Developer Exchange at ni.com/exchange. National Instruments Application Engineers make sure every question receives an answer.

    For information about other technical support options in your area, visit ni.com/services or contact your local office at ni.com/contact.
- **Training and Certification**—Visit ni.com/training for self-paced training, eLearning virtual classrooms, interactive CDs, and Certification program information. You also can register for instructor-led, hands-on courses at locations around the world.
- **System Integration**—If you have time constraints, limited in-house technical resources, or other project challenges, National Instruments Alliance Partner members can help. To learn more, call your local NI office or visit ni.com/alliance.
- **Declaration of Conformity (DoC)**—A DoC is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electronic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting ni.com/certification.

- **Calibration Certificate**—If your product supports calibration, you can obtain the calibration certificate for your product at `ni.com/calibration`.

If you searched `ni.com` and could not find the answers you need, contact your local office or NI corporate headquarters. Phone numbers for our worldwide offices are listed at the front of this manual. You also can visit the Worldwide Offices section of `ni.com/niglobal` to access the branch office Web sites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

Glossary

Symbol	Prefix	Value
k-	kilo	10^{3}
µ-	micro	10^{-6}
m-	milli	10^{-3}
M-	mega	10^{6}
n-	nano	10^{-9}

Numbers/Symbols

°	degrees
–	negative of, or minus
<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
Ω	ohms
/	per
%	percent
±	plus or minus
+	positive of, or plus
+5 V (signal)	+5 VDC source signal

A

A	amps
ACK	Acknowledge—handshaking signal driven by the NI 653*X*, indicating that it is ready to transfer data.
ADE	Application Development Environment
API	Application Programming Interface—a standardized set of subroutines or functions along with the parameters that a program can call.
asynchronous	For hardware, it is a property of an event that occurs at an arbitrary time, without synchronization to a reference clock. In software, it is the property of a function that begins an operation and returns prior to the completion or termination of the operation.

B

b	bits
B	bytes
bidirectional data lines	Data lines that can be programmatically configured as input or output.
buffer	Temporary storage for acquired or generated data (software).
bus	The group of conductors that interconnect individual circuitry in a computer. Typically, a bus is the expansion vehicle to which I/O or other devices are connected.

C

cache	High-speed processor memory that buffers commonly used instructions or data to increase processing throughput.
clock	Hardware component that controls timing for reading from or writing to groups.
CH	channel

channel	Pin or wire lead to which you apply or from which you read the analog or digital signal. For digital signals, you group channels to form ports. Ports usually consist of either four or eight digital channels.
CompactPCI	Core specification defined by the PCI Industrial Computer Manufacturer's Group (PICMG).
compiler	A software utility that converts a source program in a high-level programming language, such as LabVIEW, Basic, C or Pascal, into an object or compiled program in machine language. Compiled programs run 10 to 1,000 times faster than interpreted programs. Some languages, such as Java, are compiled to an intermediate language that is interpreted at run time.
control signals	Signals that regulate/control the timing of your data transfer in handshaking I/O and pattern I/O. There are four control signals in your NI 653*X*: ACK (STARTTRIG), REQ, STOPTRIG, and PCLK.
counter/timer	A circuit that counts external pulses or clock pulses (timing).
CPULL	A user-configurable 2.2 kΩ internal resistor for control lines. You can connect the line to +5 VDC (*pull up*) or connect the line to ground (*pull down*).
current sinking	The ability to dissipate current for analog or digital signals.
current sourcing	The ability to supply current for analog or digital signals.

D

DAQ	Data Acquisition—Collecting and measuring electrical signals from sensors, transducers, and test probes or fixtures and inputting them to a computer for processing. Also refers to collecting and measuring the same kinds of electrical signals with analog-to-digital and/or digital devices plugged into a PC, and possibly generating control signals with digital-to-analog and/or digital devices in the same PC.
Data In Valid	Data generated by peripheral device that is ready for input to the NI 653*X*.
DC	direct current
default setting	A default parameter value recorded in the driver. In many cases, the default input of a control is a certain value (often 0) that means *use the current default setting*.

device	A plug-in data acquisition board, card, or pad that can contain multiple channels and conversion devices. Plug-in boards, PCMCIA cards, and devices that connects to your computer parallel port, are all examples of DAQ devices.
DGND	digital ground
digital trigger	A TTL-level signal having two discrete levels—a high and a low level.
DIO	digital input/output
DMA	Direct Memory Access—a method by which data can be transferred to or from computer memory from or to a device or memory on the bus while the processor does something else. DMA is the fastest method of transferring data to or from computer memory.
DPULL	A user-configurable 100 kΩ internal resistor for data lines. You can connect the line to +5 VDC (*pull up*) or connect the line to ground (*pull down*).

F

FIFO	First-In First-Out memory buffer—the first data stored is the first data sent to the acceptor. FIFOs are often used on DAQ devices to temporarily store incoming or outgoing data until that data can be retrieved or output. For example, an analog input FIFO stores the results of A/D conversions until the data can be retrieved into system memory, a process that requires the servicing of interrupts and often the programming of the DMA controller. This process can take several milliseconds in some cases. During this time, data accumulates in the FIFO for future retrieval. With a larger FIFO, longer latencies can be tolerated. In the case of analog output, a FIFO permits faster update rates, because the waveform data can be stored on the FIFO ahead of time. This again reduces the effect of latencies associated with getting the data from system memory to the DAQ device.
function	A set of software instructions executed by a single line of code that may have input and/or output parameters and returns a value when executed.

G

group	A collection of one, two, or four ports and an associated timing controller. All buffered operations must be performed on groups.

H

handshaking I/O	Data-transfer mode in which the NI 653*X* engages in a two-way communication with the peripheral device. The NI 653*X* asserts a signal, ACK, when it is ready for a data transfer and the peripheral device asserts a separate signal, REQ, when it is ready for a data transfer. Data is transferred only when both the NI 653*X* and the peripheral device are ready.

I

I/O	input/output—a transfer of data to/from a computer system involving communications channels, operator interface devices, and/or data acquisition and control interfaces.
interrupt	A computer signal indicating that the CPU should suspend its current task to service a designated activity.
I_{OL}	current output high—minimum amount of available current on the output pin when the logic device is driving a logic high.
I_{OH}	current output low—minimum amount of available current on the output pin when the logic device is driving a logic low.

L

line	Individual digital bit.
low/high	Refers to the active, or “on” state of handshaking I/O lines. For example, if ACK is *active low*, the NI 653*X* is ready when its ACK line asserts (changes to) low.
LSB	least significant bit

M

Measurement & Automation Explorer (MAX)	A controlled centralized configuration environment that allows you to configure all of your NI devices.
MB/s	A unit for data transfer that means one million or 10^6 bits per second.

mask	The bits that are significant for pattern detection, also applies to change detection.
MSB	most significant bit

O

open collector	Output driver that drives its output pin to 0 V for logic low, but puts the pin in the high-impedance state for logic high.

P

pattern I/O	Data-transfer mode in which NI 653*X* transfers data on the falling or rising edge of a TTL signal, typically at a constant rate.
PCI	Peripheral Component Interconnect—A high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA. It has achieved widespread acceptance as a standard for PCs and workstations; it offers a theoretical maximum transfer rate of 132 MB/s.
PCLK	*See* control signals
PCMCIA	An expansion bus architecture that has found widespread acceptance as a de facto standard in notebook-sized computers. It originated as a specification for add-on memory cards written by the Personal Computer Memory Card International Association.
peripheral device	Any external device connected to the NI 653*X* that the NI 653*X* controls, monitors, tests, or with which it communicates.
PLL	phase lock loop
Plug and Play ISA	A specification prepared by Microsoft, Intel, and other PC-related companies that will result in PCs with plug-in boards that can be fully configured in software, without jumpers or switches on the devices.
port	A collection of lines, usually eight.
posttrigger	Acquiring data that occurs after a trigger.
PPI	programmable peripheral interface
pretrigger	Acquiring data that occurs before a trigger.

propagation delay	The amount of time required for a signal to pass through a circuit.
protocol	The exact sequence of bits, characters and control codes used to transfer data between computers and peripherals through a communications channel, such as the GPIB.
PXI	PCI eXtensions for Instrumentation—a rugged, open system for modular instrumentation based on CompactPCI, with special mechanical, electrical, and software features.

R

real time	A property of an event or system in which data is processed as it is acquired instead of being accumulated and processed at a later time.
REQ	Request—Handshaking signal generated by the peripheral device, indicating it is ready. In some transfer modes, the NI 653*X* can internally generate a REQ signal. The REQ signal with a bar above the name indicates it is an inverted request signal.
RGND	reserved ground
RT Series DAQ device	A collection of one, two, or four ports and an associated timing controller. All handshaking I/O, pattern I/O and buffered operations must be performed on groups.
RTSI bus	Real-Time System Integration Bus—the National Instruments timing bus that connects DAQ devices directly, by means of connectors on top of the devices, for precise synchronization of functions

S

s	seconds
S	samples
S/s	samples per second—used to express the rate at which a DAQ device samples an analog signal.
sample	An instantaneous measurement of a signal, normally using an analog-to-digital convertor in a DAQ device.

sample rate	The number of samples a system takes over a given time period, usually expressed in samples per second.
software trigger	A programmed event that triggers an event such as data acquisition.
static digital I/O	*See* unstrobed digital I/O
STOPTRIG	*See* control signals
Strobed I/O	Any operation where every data transfer is timed by hardware signals. In the case of pattern I/O, this hardware signal is a clock edge. In the case of handshaking I/O, hardware signals involve two or three handshaking lines.
synchronous	For hardware, it is a property of an event that is synchronized to a reference clock. For software, it is a property of a function that begins an operation and returns only when the operation is complete.

T

t_c	cycle time
t_h	hold time
t_p	propagation time to valid generated data
transfer rate	The rate, measured in bytes/s, at which data is moved from source to destination after software initialization and set up operations; the maximum rate at which the hardware can operate.
trigger	Any event that causes or starts some form of data operation.
t_{su}	setup time
TTL	transistor-transistor logic
t_w	pulse width

U

unstrobed digital I/O	Basic digital I/O operations that do not involve the use of control signals in data transfers. Unstrobed data transfers are controlled by software commands. Also known as *software-timed I/O* or *static digital I/O*.

V

V	volts
VI	Virtual Instrument—(1) a combination of hardware and/or software elements, typically used with a PC, that has the functionality of a classic stand-alone instrument (2) a LabVIEW software module (VI), which consists of a front panel user interface and a block diagram program.
V_{in}	input voltage
virtual channels	Channel names that can be defined outside the application and used without having to perform scaling operations.

W

wired-OR	*See* open collector.

Index

Numerics

+5 V signal, description (table), C-5
653*X* devices
    See also hardware; specific device name
    configuring, 1-9
    hardware considerations, D-1
    installing, 1-7
    overview, 1-1
    requirements for getting started, 1-2
    software programming choices
        National Instruments application software, 1-3
        NI-DAQ driver software, 1-4
    unpacking, 1-6
8255-emulation handshaking protocol
    comparison of protocols (table), 3-4
    input handshaking sequence (figure), 3-12
    input state machine (figure), 3-13
    maximum transfer rate (table), E-1
    output handshaking sequence (figure), 3-14
    output state machine, 3-15
    output timing diagram (figure), 3-16

A

ACK protocol. *See* level-ACK handshaking protocol
ACK<1..2> signal
    8255-emulation protocol
        input handshaking sequence (figure), 3-12
        input state machine (figure), 3-13
        output handshaking sequence (figure), 3-14
        output state machine (figure), 3-15
        output timing diagram (figure), 3-16
        overview, 3-11
burst input timing diagrams
    default input timing diagram (figure), 3-7
    PCLK reversed (figure), 3-9
    transfer example (figure), 3-6
burst output timing diagrams
    default output timing diagram (figure), 3-8
    PCLK reversed (figure), 3-10
    transfer example (figure), 3-6
connecting signals
    change detection, 2-33
    handshaking I/O, 2-21
    pattern I/O, 2-13
description (table), C-4
handshaking I/O and pattern I/O (table), C-1
leading-edge protocol
    input handshaking sequence (figure), 3-27
    input state machine (figure), 3-28
    input timing diagram (figure), 3-29
    output handshaking sequence (figure), 3-30
    output state machine (figure), 3-30
    output timing diagram (figure), 3-31
level-ACK protocol
    input handshaking sequence (figure), 3-17
    input state machine (figure), 3-18
    input timing diagram (figure), 3-19
    output handshaking sequence (figure), 3-20
    output state machine (figure), 3-20
    output timing diagram (figure), 3-21
long-pulse protocol
    input handshaking sequence (figure), 3-32
    input state machine (figure), 3-33

input timing diagram (figure), 3-34
output handshaking sequence (figure), 3-35
output state machine (figure), 3-35
output timing diagram (figure), 3-36
polarity for handshaking I/O
comparison of handshaking protocols (table), 3-4
controlling line polarity, 2-23
selecting polarity, 2-19
start and stop trigger
change detection, 2-31
pattern I/O, 2-9
start trigger
change detection, 2-30
pattern I/O, 2-8
trailing-edge protocol
input handshaking sequence (figure), 3-22
input state machine (figure), 3-23
input timing diagram (figure), 3-24
output handshaking sequence (figure), 3-25
output state machine (figure), 3-25
output timing diagram (figure), 3-26
applications, choosing correct mode for (table), 2-1
asynchronous handshaking protocol, 3-11
AT-DIO-32HS
benchmark results (table), E-4
block diagram, D-1
installation, 1-8
support for DMA transfers (table), E-3

B

benchmark results. *See* optimizing transfer rates
block diagrams
AT-DIO-32HS, D-1
DAQCard-6533 for PCMCIA, D-2
PCI/PXI-6534, D-4
PCI-DIO-32HS, PCI/PXI-7030/6533, and PXI-6533, D-3
phase-locked loop circuit (figure), D-11
burst handshaking protocol
comparison of protocols (table), 3-4
input timing diagram
default timing diagram (figure), 3-7
PCLK reversed (figure), 3-9
transfer example (figure), 3-6
maximum transfer rate (table), E-2
output timing diagram
default timing diagram (figure), 3-8
PCLK reversed (figure), 3-10
transfer example (figure), 3-6
overview, 2-18
PCLK signal direction, 2-18
bus
interface specifications, A-3
RTSI
overview, 1-1
RTSI and PXI trigger bus interfaces, D-10

C

cable selection and termination
Schottky-diode termination scheme, D-7
transmission line termination (figure), D-8
calibration certificate (NI resources), F-2
change detection
connecting signals, 2-33
continuous or finite data transfer
continuous input, 2-32
DMA or interrupt transfers, 2-33
finite, 2-32
overview, 2-28
port and timing controller combinations (table), 2-28

programming
continuous change detection in NI-DAQ (figure), 2-34
LabVIEW/LabVIEW RT (figure), 2-35
single buffer change detection in NI-DAQ (figure), 2-34
specifications, A-3
specifying lines to monitor, 2-29
triggering data transfer
pattern-matching trigger, 2-31
start and stop trigger, 2-31
start trigger, 2-30
stop trigger, 2-30
when to use (table), 2-1
width of data to acquire, 2-28
clocks, for RTSI and PXI trigger bus interfaces, D-10
CompactPCI, using with PXI, B-1
configuration, 653*X* devices
Mac OS, 1-10
Windows, 1-9
configuration, ports, 2-6
connecting signals. *See* signal connections
continuous or finite data transfer
change detection
continuous input, 2-32
DMA or interrupt transfers, 2-33
finite, 2-32
handshaking I/O
continuous input, 2-20
continuous output, 2-20
DMA or interrupt transfers, 2-21
finite, 2-20
pattern I/O
continuous input, 2-11
continuous output, 2-11
DMA or interrupt transfers, 2-12
finite, 2-11
control lines
Group 1 and Group 2 controllers, 1-2
handshaking I/O and pattern I/O (table), C-1
using as extra unstrobed data lines, 2-3
conventions used in the manual, *v*
CPULL signal
description (table), C-5
power-on state, D-5

D

DAQCard-6533 for PCMCIA
benchmark results (table), E-7
block diagram, D-2
installation, 1-9
data transfer
change detection
continuous or finite data transfer, 2-32
triggering data transfer, 2-30
width of data to acquire, 2-28
handshaking I/O
continuous or finite data transfer, 2-20
direction of data transfer, 2-17
width of data to transfer, 2-17
optimizing transfer rates
benchmark results, E-3
maximum transfer rates, E-1
obtaining fastest transfer rates, E-2
pattern I/O
continuous or finite data transfer, 2-11
direction of data transfer, 2-7
monitoring data transfer, 2-12
rate of data transfer, 2-8
triggering data transfer, 2-8
width of data to transfer, 2-6
Declaration of Conformity (NI resources), F-1

delay, programmable, handshaking protocol, 2-19
diagnostic tools (NI resources), F-1
digital I/O specifications, A-1
digital lines. *See* static digital lines
digital patterns and waveforms. *See* pattern I/O
DIOA<0..7> signal (table), C-4
DIOB<0..7> signal (table), C-4
DIOC<0..7> signal (table), C-5
DIOD<0..7> signal (table), C-5
DMA or interrupt transfers
  change detection, 2-33
  devices that support DMA transfers (table), E-3
  handshaking I/O, 2-21
  pattern I/O, 2-12
documentation
  conventions used in the manual, *v*
  NI resources, F-1
DPULL signal
  description (table), C-5
  power-on state, D-5
drivers (NI resources), F-1

E

edge-based handshaking protocols. *See* signal edge-based handshaking protocols
environment specifications, A-4
equipment, optional, for connecting signals, C-7
examples (NI resources), F-1
extra data lines, using Group 1 and Group 2 control lines, 2-3

F

finite data transfer. *See* continuous or finite data transfer

G

GND signal, description (table), C-5
Group 1 and Group 2
  introduction, 1-2
  using control lines as extra unstrobed data lines, 2-3

H

handshaking I/O
  See also handshaking I/O timing diagrams
  ACK/REQ signal polarity, 2-19
  connecting signals, 2-21
  continuous or finite data transfer
    continuous input, 2-20
    continuous output, 2-20
    DMA or interrupt transfers, 2-21
    finite, 2-20
  direction of data transfer, 2-17
  maximum transfer rates (table), E-1
  port and timing controller combinations (table), 2-17
  programming
    buffered handshaking I/O in NI-DAQ (figure), 2-24
    handshaking input in LabVIEW/LabVIEW RT (figure), 2-26
    handshaking output in LabVIEW/LabVIEW RT (figure), 2-27
    unbuffered handshaking I/O in NI-DAQ (figure), 2-25
  programming delay, 2-19
  protocols
    burst protocol, 2-18
    deciding on a protocol, 2-17
  startup sequence
    controlling line polarities, 2-23
    initialization order, 2-22

when to use (table), 2-1
width of data to transfer, 2-17
handshaking I/O timing diagrams
8255-emulation protocol
input handshaking sequence (figure), 3-12
input state machine (figure), 3-13
output handshaking sequence (figure), 3-14
output state machine (figure), 3-15
output timing diagram (figure), 3-16
asynchronous protocol, 3-11
burst protocol input timing diagram
default timing diagram (figure), 3-7
PCLK reversed (figure), 3-9
transfer example (figure), 3-6
burst protocol output timing diagram
default timing diagram (figure), 3-8
PCLK reversed (figure), 3-10
transfer example (figure), 3-6
comparing different protocols (table), 3-4
leading-edge protocol
input handshaking sequence (figure), 3-27
input state machine (figure), 3-28
input timing diagram (figure), 3-29
output handshaking sequence (figure), 3-30
output state machine (figure), 3-30
output timing diagram (figure), 3-31
level-ACK protocol
input handshaking sequence (figure), 3-17
input state machine (figure), 3-18
input timing diagram (figure), 3-19
output handshaking sequence (figure), 3-20
output state machine (figure), 3-20
output timing diagram (figure), 3-21
long-pulse protocol
input handshaking sequence (figure), 3-32
input state machine (figure), 3-33
input timing diagram (figure), 3-34
output handshaking sequence (figure), 3-35
output state machine (figure), 3-35
output timing diagram (figure), 3-36
signal edge-based protocols, 3-22
trailing-edge protocol
input handshaking sequence (figure), 3-22
input state machine (figure), 3-23
input timing diagram (figure), 3-24
output handshaking sequence (figure), 3-25
output state machine (figure), 3-25
output timing diagram (figure), 3-26
hardware
block diagrams
AT-DIO-32HS, D-1
DAQCard-6533 for PCMCIA, D-2
PCI/PXI-6534, D-4
PCI-DIO-32HS, PCI/PXI-7030/6533, and PXI-6533, D-3
cable selection and termination
Schottky-diode termination scheme, D-7
transmission line terminations (figure), D-8
configuration
Mac OS, 1-10
Windows, 1-9
installation
AT-DIO-32HS, 1-8
DAQCard-6533 for PCMCIA, 1-9
PCI-DIO-32HS, PCI-6534, or PCI-7030/6533 devices, 1-7

PXI-6533, PXI-6534, or PXI-7030/6533 devices, 1-7
software, 1-6
unpacking 653*X* devices, 1-6
power connections, D-5
power-on state, D-5
RTSI and PXI trigger bus interfaces
board, RTSI, and PXI bus clocks, D-10
RTSI and PXI bus triggers, D-11
sink and source current, D-9
hardware overview
block diagrams, D-1
phase-locked loop circuit, D-10
power connections, D-5
power-on state, D-5
RTSI and PXI bus interfaces, D-10
help, technical support, F-1

I

initialization order, handshaking I/O, 2-22
installation
AT-DIO-32HS, 1-8
category, 1-11
DAQCard-6533 for PCMCIA, 1-9
PCI-DIO-32HS, PCI-6534, or PCI-7030/6533 devices, 1-7
PXI-6533, PXI-6534, or PXI-7030/6533 devices, 1-7
software, 1-6
unpacking 653*X* devices, 1-6
instrument drivers (NI resources), F-1
instrument drivers, NI-DAQ, 1-4
interrupt transfers. *See* DMA or interrupt transfers

K

KnowledgeBase, F-1

L

LabVIEW and LabVIEW RT software, 1-3
leading-edge handshaking protocol
comparison of protocols (table), 3-4
definition, 3-22
input handshaking sequence (figure), 3-27
input state machine (figure), 3-28
input timing diagram (figure), 3-29
maximum transfer rate (table), E-1
output handshaking sequence (figure), 3-30
output state machine (figure), 3-30
output timing diagram (figure), 3-31
level-ACK handshaking protocol
comparison of protocols (table), 3-4
input handshaking sequence (figure), 3-17
input state machine (figure), 3-18
input timing diagram (figure), 3-19
maximum transfer rate (table), E-1
output handshaking sequence (figure), 3-20
output state machine (figure), 3-20
output timing diagram (figure), 3-21
line state, monitoring. *See* change detection
long-pulse handshaking protocol
comparison of protocols (table), 3-4
definition, 3-22
input handshaking sequence (figure), 3-32
input state machine (figure), 3-33
input timing diagram (figure), 3-34
maximum transfer rate (table), E-2
output handshaking sequence (figure), 3-35
output state machine (figure), 3-35
output timing diagram (figure), 3-36

M

Measurement Studio software, 1-3
memory specifications, A-2
monitoring data transfer, pattern I/O, 2-12
monitoring line state. *See* change detection

N

National Instruments support and services, F-1
National Instruments, application software, 1-3
NI support and services, F-1
NI-DAQ driver software, overview, 1-4

O

open-collector output, unstrobed I/O, 2-2
optimizing transfer rates
  benchmark results
    AT-DIO-32HS (table), E-4
    DAQCard-6533 for PCMCIA (table), E-7
    PCI-6534 (table), E-8
    PCI-7030/6533 with LabVIEW RT (table), E-10
    PCI-DIO-32HS (table), E-5
    PXI-6533 (table), E-6
    PXI-6533 with LabVIEW RT, E-10
    PXI-6534 (table), E-9
  maximum transfer rates, E-1
  obtaining fastest transfer rates, E-2
optional equipment for connecting signals, C-7

P

pattern I/O
  connecting signals, 2-13
  continuous or finite data transfer
    continuous input, 2-11
    continuous output, 2-11
    DMA or interrupt transfers, 2-12
    finite, 2-11
  internal or external REQ source, 2-7
  maximum transfer rate (table), E-2
  monitoring data transfer, 2-12
  port and timing controller combinations (table), 2-6
  programming
    continuous, in NI-DAQ, 2-15
    LabVIEW/LabVIEW RT, 2-16
    single buffer, in NI-DAQ, 2-14
  REQ polarity, 2-7
  specifications, A-3
  timing diagrams
    external REQ signal source, 3-2
    internal REQ signal source, 3-1
  transfer direction, 2-7
  transfer rate, 2-8
  triggering data transfer
    pattern-matching trigger (input only), 2-10
    start and stop trigger, 2-9
    start trigger, 2-8
    stop trigger, 2-9
  when to use (table), 2-1
  width of data to transfer, 2-6
pattern-matching trigger
  change detection, 2-31
  input only, pattern I/O, 2-10
PCI-6534 device
  benchmark results (table), E-8
  block diagram, D-4
  installation, 1-7
  support for DMA transfers (table), E-3
PCI-7030/6533 device
  benchmark results (table), E-10
  block diagram, D-3
  installation, 1-7
PCI-DIO-32HS
  benchmark results (table), E-5
  block diagram, D-3

installation, 1-7
support for DMA transfers (table), E-3
PCLK<1..2> signal
burst input timing diagrams
default input timing diagram (figure), 3-7
PCLK reversed (figure), 3-9
transfer example (figure), 3-6
burst output timing diagrams
output timing diagram (figure), 3-8
PCLK reversed (figure), 3-10
transfer example (figure), 3-6
description (table), C-4
frequency selection for programmable delay, 2-19
handshaking I/O and pattern I/O (table), C-1
signal direction for burst protocol, 2-18
phase-locked loop circuit
block diagram, D-11
description, D-10
physical specifications, A-4
pin assignments
50-pin signal connections (figure), C-6
68-pin signal connections (figure), C-2
PLL. *See* phase-locked loop circuit, D-10
polarity
ACK/REQ signals, 2-19
comparison of handshaking protocols (table), 3-4
controlling line polarities, 2-23
Port 4 lines (table), 2-4
ports, configuring, 2-6
power connections, D-5
power specifications
power available at I/O connector, A-4
power requirements, A-4
power-on state, D-5
programmable delay, handshaking protocol, 2-19
programming
See also software programming choices
change detection
continuous change detection in NI-DAQ (figure), 2-34
LabVIEW/LabVIEW RT (figure), 2-35
single buffer change detection in NI-DAQ (figure), 2-34
handshaking I/O
buffered handshaking I/O in NI-DAQ (figure), 2-24
handshaking input in LabVIEW/LabVIEW RT (figure), 2-26
handshaking output in LabVIEW/LabVIEW RT (figure), 2-27
unbuffered handshaking I/O in NI-DAQ (figure), 2-25
pattern I/O
continuous, in NI-DAQ (figure), 2-15
LabVIEW/LabVIEW RT (figure), 2-16
single buffer, in NI-DAQ (figure), 2-14
unstrobed I/O
control/timing lines as extra unstrobed data lines, 2-5
flowcharts, 2-5
programming examples (NI resources), F-1
PXI bus interface. *See* RTSI and PXI trigger bus interfaces
PXI, using with CompactPCI, B-1
PXI-6533 device
benchmark results (table), E-6
installation, 1-7
support for DMA transfers (table), E-3
with LabVIEW RT, E-10
PXI-6534 device
benchmark results (table), E-9

block diagram, D-4
installation, 1-7
support for DMA transfers (table), E-3
PXI-7030/6533 devices
block diagram, D-3
installation, 1-7

R

Real-Time System Integration. *See* RTSI
REQ<1..2> signal
8255-emulation protocol
input handshaking sequence (figure), 3-12
input state machine (figure), 3-13
output handshaking sequence (figure), 3-14
output state machine (figure), 3-15
output timing diagram (figure), 3-16
overview, 3-11
and the STARTTRIG signal, 3-3
burst input timing diagrams
default input timing diagram (figure), 3-7
PCLK reversed (figure), 3-9
transfer example (figure), 3-6
burst output timing diagrams
default output timing diagram (figure), 3-8
PCLK reversed (figure), 3-10
transfer example (figure), 3-6
connecting signals
handshaking I/O, 2-21
pattern I/O, 2-13
description (table), C-4
handshaking I/O and pattern I/O (table), C-1
leading-edge protocol
input handshaking sequence (figure), 3-27
input state machine (figure), 3-28
input timing diagram (figure), 3-29
output handshaking sequence (figure), 3-30
output state machine (figure), 3-30
output timing diagram (figure), 3-31
level-ACK protocol
input handshaking sequence (figure), 3-17
input state machine (figure), 3-18
input timing diagram (figure), 3-19
output handshaking sequence (figure), 3-20
output state machine (figure), 3-20
output timing diagram (figure), 3-21
long-pulse protocol
input handshaking sequence (figure), 3-32
input state machine (figure), 3-33
input timing diagram (figure), 3-34
output handshaking sequence (figure), 3-35
output state machine (figure), 3-35
output timing diagram (figure), 3-36
polarity for handshaking I/O
comparison of handshaking protocols (table), 3-4
controlling line polarity, 2-23
selecting polarity, 2-19
polarity for pattern I/O, 2-7
signal source for pattern I/O
choosing internal or external source, 2-7
external REQ signal source, 3-2
internal REQ signal source, 3-1
trailing-edge protocol
input handshaking sequence (figure), 3-22
input state machine (figure), 3-23
input timing diagram (figure), 3-24
output handshaking sequence (figure), 3-25

output state machine (figure), 3-25
output timing diagram (figure), 3-26
requirements for getting started, 1-2
RGND signal (table), C-5
RTSI
overview, 1-1
RTSI and PXI trigger bus interfaces
board, RTSI, and PXI bus clocks, D-10
RTSI and PXI bus triggers, D-11
trigger specifications, A-3

S

Schottky-diode termination scheme, D-7
signal connections
50-pin signal connections
accessories (table), C-7
pin assignments (figure), C-6
68-pin signal connections
accessories (table), C-3
pin assignments (figure), C-2
change detection, 2-33
control signals (table), C-1
handshaking I/O, 2-21
optional equipment, C-7
pattern I/O, 2-13
signal descriptions (table), C-4
static digital lines, 2-4
signal edge-based handshaking protocols
comparison of protocols (table), 3-4
leading-edge protocol, 3-27
long-pulse protocol, 3-32
trailing-edge handshaking protocol, 3-22
types of protocols, 3-22
sink current, D-9
software (NI resources), F-1
software installation, 1-6
software programming choices
National Instruments application software, 1-3
NI-DAQ driver software, 1-4
source current, D-9
specifications
bus interfaces, A-3
change detection, A-3
digital I/O, A-1
environment, A-4
memory, A-2
pattern I/O, A-3
physical, A-4
power available at I/O connector, A-4
power requirements, A-4
triggers
RTSI triggers (PCI, PXI, AT), A-3
start and stop triggers, A-3
standard output, unstrobed I/O, 2-2
start and stop trigger
change detection, 2-31
pattern I/O, 2-9
trigger specifications, A-3
start trigger
change detection, 2-30
pattern I/O, 2-8
STARTTRIG<1..2> signal
and the REQ signal, 3-3
control signals for handshaking I/O and pattern I/O (table), C-1
startup sequence for handshaking I/O
controlling line polarities, 2-23
initialization order, 2-22
static digital lines
configuring
open-collector output, 2-2
standard output, 2-2
connecting signals, 2-4
controlling and monitoring, 2-2
Port 4 lines (table), 2-4
programming unstrobed I/O
control/timing lines as extra unstrobed data lines, 2-5
flowcharts, 2-5

using control lines as extra unstrobed data lines, 2-3
stop trigger
See also start and stop trigger
change detection, 2-30
pattern I/O, 2-9
STOPTRIG<1..2> signal
connecting signals
change detection, 2-33
pattern I/O, 2-13
description (table), C-4
handshaking I/O and pattern I/O (table), C-1
start and stop trigger
change detection, 2-31
pattern I/O, 2-9
stop trigger
change detection, 2-30
pattern I/O, 2-9
support, technical, F-1

T

technical support, F-1
terminating cables. *See* cable selection and termination
timing diagrams
handshaking I/O
8255-emulation protocol, 3-11
asynchronous protocols, 3-11
burst protocols, 3-5
comparing different protocols (table), 3-4
edge-based protocols, 3-22
leading-edge protocol, 3-27
level-ACK protocol, 3-17
long-pulse protocol, 3-32
trailing-edge protocol, 3-22
pattern I/O
external REQ signal source, 3-2
internal REQ signal source, 3-1
trailing-edge handshaking protocol
comparison of protocols (table), 3-4
definition, 3-22
input handshaking sequence (figure), 3-22
input state machine (figure), 3-23
input timing diagram (figure), 3-24
maximum transfer rate (table), E-2
output handshaking sequence (figure), 3-25
output state machine (figure), 3-25
output timing diagram (figure), 3-26
training and certification (NI resources), F-1
transferring data. *See* data transfer
trigger bus interfaces. *See* RTSI and PXI trigger bus interfaces
trigger specifications
RTSI triggers (PCI, PXI, AT), A-3
start and stop triggers, A-3
triggering data transfer
change detection
pattern-matching trigger, 2-31
start and stop trigger, 2-31
start trigger, 2-30
stop trigger, 2-30
pattern I/O
pattern-matching trigger (input only), 2-10
start and stop trigger, 2-9
start trigger, 2-8
stop trigger, 2-9
troubleshooting (NI resources), F-1

U

unpacking 653*X* devices, 1-6
unstrobed I/O
configuring digital lines
open-collector output, 2-2
standard output, 2-2
Port 4 lines (table), 2-4

programming
control/timing lines as extra unstrobed data lines, 2-5
flowcharts, 2-5
using control lines as extra unstrobed data lines, 2-3
when to use (table), 2-1

V

voltage-controlled crystal oscillator (VCXO), D-11

W

waveforms. *See* pattern I/O
Web resources, F-1

Artisan Technology Group is an independent supplier of quality pre-owned equipment

Gold-standard solutions

Extend the life of your critical industrial, commercial, and military systems with our superior service and support.

We buy equipment

Planning to upgrade your current equipment? Have surplus equipment taking up shelf space? We'll give it a new home.

Learn more!

Visit us at **artisantg.com** for more info on price quotes, drivers, technical specifications, manuals, and documentation.

Artisan Scientific Corporation dba Artisan Technology Group is not an affiliate, representative, or authorized distributor for any manufacturer listed herein.

We're here to make your life easier. How can we help you today?

(217) 352-9330 | sales@artisantg.com | artisantg.com

ARTISAN® TECHNOLOGY GROUP