DeviceNet™

NI-DNET™ User Manual

May 2004 Edition
Part Number 370375B-01

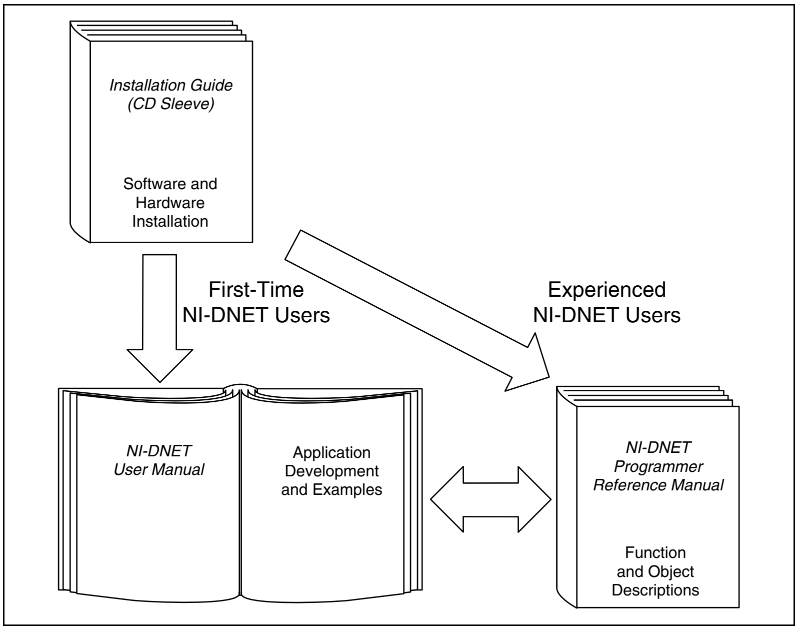
Important Information

Contents

About This Manual

This manual describes the basics of DeviceNet and explains how to develop an application program, including reference to examples. The user manual also contains hardware information.

How to Use the Manual Set


Installation Guide (CD Sleeve)
Software and Hardware Installation
First-Time NI-DNET Users
Experienced NI-DNET Users
NI-DNET User Manual
Application Development and Examples
NI-DNET Programmer Reference Manual
Function and Object Descriptions

Use the installation guide to install and configure your DeviceNet hardware and the NI-DNET software.

Use this *NI-DNET User Manual* to learn the basics of DeviceNet and how to develop an application program. The user manual also contains information on DeviceNet hardware.

Use the *NI-DNET Programmer Reference Manual* for specific information about each NI-DNET function and object.

Conventions

The following conventions appear in this manual:

»	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 open the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.
✎	This icon denotes a note, which alerts you to important information.
bold	Bold text denotes items that you must select or click on 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, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.

Related Documentation

The following documents contain information that you might find helpful as you read this manual:

- ANSI/ISO Standard 11898-1993, *Road Vehicles—Interchange of Digital Information—Controller Area Network (CAN) for High-Speed Communication*
- *DeviceNet Specification, Version 2.0*, Open DeviceNet Vendor Association
- *CompactPCI Specification*, Revision 2.0, PCI Industrial Computers Manufacturers Group
- *PXI Hardware Specification*, Revision 2.1, National Instruments Corporation
- *PXI Software Specification*, Revision 2.1, National Instruments Corporation

- LabVIEW online reference
- ODVA website, `www.odva.org`
- Microsoft Win32 Software Development Kit (SDK) online help

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NI-DNET Software Overview

The DeviceNet software provided with National Instruments DeviceNet hardware is called NI-DNET. This section provides an overview of the NI-DNET software.

Installation and Configuration

Measurement & Automation Explorer (MAX)

Measurement & Automation Explorer (MAX) provides access to all of your National Instruments products. Like other NI software products, NI-DNET uses MAX as the centralized location for all configuration and tools.

To launch MAX, select the **Measurement & Automation** shortcut on your desktop, or within your Windows **Programs** menu under **National Instruments»Measurement & Automation**.

For information about the NI-DNET software within MAX, consult the MAX online help. A reference is in the MAX **Help** menu under **Help Topics»NI-DNET**.

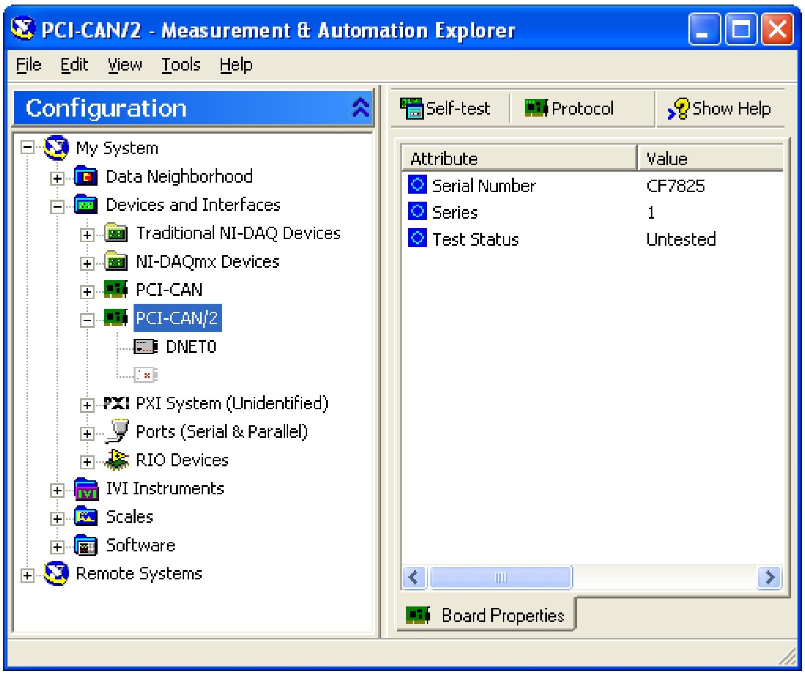
View help for items in the MAX **Configuration** tree by using the built-in MAX help pane. If this help pane is not shown on the far right, select the **Show/Hide** button in the upper right.

View help for a dialog box by selecting the **Help** button in the window.

The following sections provide an overview of some common tasks you can perform within MAX.

Verify Installation of Your DeviceNet Hardware

Within the **Devices & Interfaces** branch of the MAX **Configuration** tree, NI DeviceNet cards are listed along with other hardware in the local computer system, as shown in Figure 1-1.



Attribute	Value
Serial Number	CF7825
Series	1
Test Status	Untested

Figure 1-1. NI-DNET Cards Listed in MAX

Note Each card's name uses the word CAN, because the Controller Area Network is the communication protocol upon which DeviceNet is built.

If your NI DeviceNet hardware is not listed here, MAX is not configured to search for new devices on startup. To search for the new hardware, press <F5>.

To verify installation of your DeviceNet hardware, right-click the DeviceNet card, then select **Self-test**. If the self-test passes, the card icon shows a checkmark. If the self-test fails, the card icon shows an *X* mark, and the **Test Status** in the right pane describes the problem. Refer to Appendix C, *Troubleshooting and Common Questions*, for information about resolving hardware installation problems.

Configure DeviceNet Port

The physical port of each DeviceNet card is listed under the card's name. To configure software properties, right-click the port and select **Properties**.

In the **Properties** dialog, you assign an interface name to the port, such as **DNET0** or **DNET1**. The interface name identifies the physical port within NI-DNET APIs.

Change Protocol

To change the default protocol for the DeviceNet (CAN) card, right-click the card and select **Protocol**. In this dialog you can select either **DeviceNet** for NI-DNET (default), or **CAN** for NI-CAN. For more information, refer to the section *Using NI-CAN with NI-DNET*.

LabVIEW Real-Time (RT) Configuration

LabVIEW Real-Time (RT) combines easy-to-use LabVIEW programming with the power of real-time systems. When you use a National Instruments PXI controller as a LabVIEW RT system, you can install a PXI DeviceNet card and use the NI-DNET APIs to develop real-time applications. For example, you can control a network of DeviceNet devices as a master, and write your control algorithm in LabVIEW.

When you install the NI-DNET software, the installer checks for the presence of the LabVIEW RT module. If LabVIEW RT exists, the NI-DNET installer copies components for LabVIEW RT to your Windows system. As with any other NI product for LabVIEW RT, you then download the NI-DNET and NI-CAN software to your LabVIEW RT system using the **Remote Systems** branch in MAX. For more information, refer to the LabVIEW RT documentation.

After you have installed your PXI DeviceNet cards and downloaded the NI-DNET software to your LabVIEW RT system, you need to verify the installation. Within the **Tools** menu in MAX, select **NI-DNET» RT Hardware Configuration**. The **RT Hardware Configuration** tool provides features similar to **Devices & Interfaces** on your local system. Use the **RT Hardware Configuration** tool to self-test the DeviceNet cards and assign an interface name to each physical DeviceNet port.

Tools

NI-DNET provides tools that you can launch from MAX.

NI-Spy

This tool monitors function calls to the NI-DNET APIs. This tool helps in debugging programming problems in your application. To launch this tool, open the **Software** branch of the MAX Configuration tree, right-click **NI Spy**, and select **Launch NI Spy**.

SimpleWho

To provide valid parameters for the NI-DNET open functions (`ncOpenDnetIntf`, `ncOpenDnetExplMsg`, and `ncDnetOpenIO`), you need to determine some basic information about your DeviceNet devices. This information includes the MAC ID of each device, the I/O connections it supports, and the input/output lengths for those I/O connections.

In most cases, the vendor of each DeviceNet device provides this information, but if not, NI-DNET provides a tool that helps you determine this information. Searching a DeviceNet network to determine information about connected devices is often referred to as a *network who*, and thus the NI-DNET tool is called **SimpleWho**. This tool is not a complete network management or configuration tool. It provides read-only information about the DeviceNet devices connected to your National Instruments DeviceNet interface.

To launch **SimpleWho**, right-click the DeviceNet interface (such as **DNET0**) in MAX, and select **SimpleWho**.

For more information on the **SimpleWho** tool, refer to the NI-DNET help file in MAX. This help file can be opened using the **Help** button in the **SimpleWho** tool itself.

NI-DNET Objects

The NI-DNET software, like the DeviceNet Specification, uses object-oriented concepts to represent components in the DeviceNet system (for more information about object-oriented concepts in the DeviceNet Specification, refer to Appendix A, *DeviceNet Overview*). However, whereas in the DeviceNet Specification objects represent a multitude of components in DeviceNet devices, NI-DNET objects represent components of the Windows device driver software. The NI-DNET device driver objects do not correspond directly to objects contained in remote devices. To facilitate access to the DeviceNet network, the NI-DNET objects provide a more concise representation of various objects defined in the DeviceNet Specification.

Much like any other object-oriented system, NI-DNET device driver objects use the concepts of class, instance, attribute, and service to describe their features. The NI-DNET device driver software provides three classes of objects: Interface Objects, Explicit Messaging Objects, and I/O Objects. You can open an instance of an NI-DNET object using one of the three open functions (`ncOpenDnetExplMsg`, `ncOpenDnetIntf`, or `ncOpenDnetIO`). The services for an NI-DNET object are accomplished using the NI-DNET functions, which can be called directly from your programming environment (such as Microsoft C/C++ or LabVIEW). The essential attributes of an NI-DNET object are initialized using its open function; you can access other attributes using `ncGetDriverAttr` or `ncSetDriverAttr`. The attributes of NI-DNET device driver objects are called *driver attributes*, to differentiate them from actual attributes in remote DeviceNet devices.

For complete information on each NI-DNET object, including its driver attributes and supported functions (services), refer to your *NI-DNET Programmer Reference Manual*.

Interface Object

The Interface Object represents a DeviceNet interface (physical DeviceNet port on your DeviceNet board). Since this interface acts as a device on the DeviceNet network much like any other device, it is configured with its own MAC ID and baud rate.

Use the Interface Object to do the following:

- Configure NI-DNET settings that apply to the entire interface
- Start and stop communication for all NI-DNET objects associated with the interface

Explicit Messaging Object

The Explicit Messaging Object represents an explicit messaging connection to a remote DeviceNet device (physical device attached to your interface by a DeviceNet cable). Since only one explicit messaging connection is created for a given device, the Explicit Messaging Object is also used for features that apply to the device as a whole.

Use the Explicit Messaging Object to do the following:

- Execute the DeviceNet Get Attribute Single service on the remote device (`ncGetDnetAttribute`)

- Execute the DeviceNet Set Attribute Single service on the remote device (`ncSetDnetAttribute`)
- Send any other explicit message request to the remote device and receive the associated explicit message response (`ncWriteDnetExplMsg`, `ncReadDnetExplMsg`)
- Configure NI-DNET settings that apply to the entire remote device

I/O Object

The I/O Object represents an I/O connection to a remote DeviceNet device (physical device attached to your interface by a DeviceNet cable). The I/O Object usually represents I/O communication as a master with a remote slave device, but it can also be used for I/O communication as a slave.

The I/O Object supports as many master/slave I/O connections as currently allowed by the DeviceNet Specification. This means that you can use polled, strobed, and COS/cyclic I/O connections simultaneously for a given device. As specified by the DeviceNet Specification, only one master/slave I/O connection of a given type can be used for each device (MAC ID). For example, you cannot open two polled I/O connections for the same device.

Use the I/O Object to do the following:

- Read data from the most recent message received on the I/O connection (`ncReadDnetIO`)
- Write data for the next message produced on the I/O connection (`ncWriteDnetIO`)

Example

Figure 1-2 shows an example of how NI-DNET objects can be used to communicate on a DeviceNet network. This example shows three DeviceNet devices. The first device (at MAC ID 1) is the National Instruments DeviceNet interface. The second device (at MAC ID 5) uses NI-DNET to access a polled and a COS I/O connection simultaneously. The third device (at MAC ID 8) uses NI-DNET to access an explicit messaging connection and a strobed I/O connection.

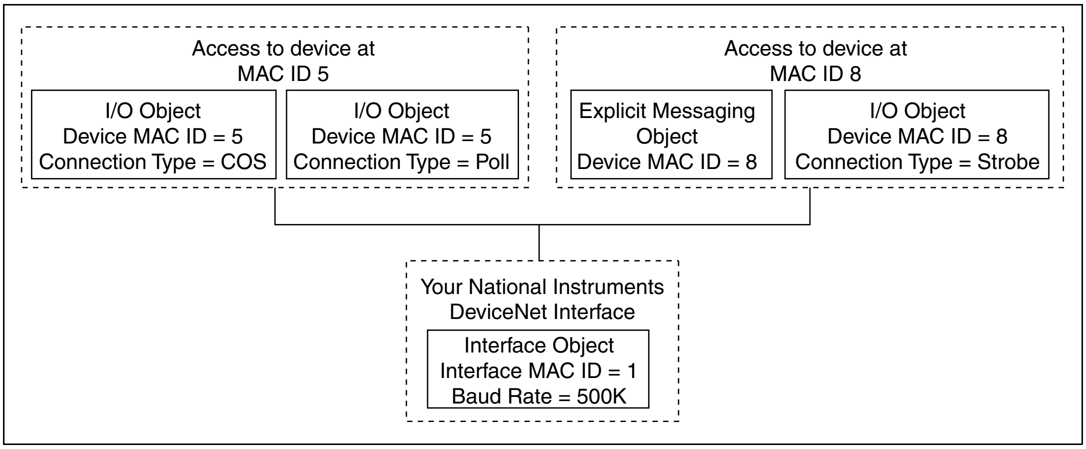

Access to device at MAC ID 5
I/O Object Device MAC ID = 5 Connection Type = COS
I/O Object Device MAC ID = 5 Connection Type = Poll
Access to device at MAC ID 8
Explicit Messaging Object Device MAC ID = 8
I/O Object Device MAC ID = 8 Connection Type = Strobe
Your National Instruments DeviceNet Interface
Interface Object Interface MAC ID = 1 Baud Rate = 500K

Figure 1-2. NI-DNET Objects for a Network of Three Devices

Using NI-CAN with NI-DNET

Controller Area Network (CAN) is the low-level protocol used for DeviceNet communications. In addition to the NI-DNET functions, your National Instruments DeviceNet hardware can also be used for low-level access to CAN messages using the NI-CAN software. NI-CAN is intended primarily for applications that require direct access to CAN messages, such as test applications for automotive (non-DeviceNet) networks. When connecting to a DeviceNet network, the NI-CAN capabilities are useful for the following applications:

- Low-level monitoring of CAN messages to determine conformance to DeviceNet specifications
- Implementation of sections of the DeviceNet Specification yourself, such as custom configuration tools

NI-CAN uses the same software infrastructure as NI-DNET, so both APIs can be used with the same CAN card. The general rule is that each CAN card can only be used for one API at a time.

Use of NI-DNET is restricted to port 1 (top port) of Series 1 CAN cards. For more information on hardware provided in CAN kits, refer to Chapter 2, *NI-DNET Hardware Overview*.

You can view each CAN card in MAX with either DeviceNet or CAN features. To change the view of a CAN card in MAX, right-click the card and select **Protocol**. In this dialog you can select either **DeviceNet** for

NI-DNET (default), or **CAN** for NI-CAN. When the CAN protocol is selected, you can access CAN tools in MAX, such as the Bus Monitor tool that displays CAN messages in their raw form.

In order to develop NI-CAN applications, you must install NI-CAN components such as documentation and examples. The NI-CAN software components are available within the NI-DNET installer.

Launch the `setup.exe` program for the NI-DNET installer in the same manner as your original installation (CD or `ni.com` download). Within the installer, select both NI-DNET and NI-CAN components in the feature tree.

When you right-click a port in MAX and select **Properties**, the resulting **Interface** selection uses the syntax `CAN`*`x`* or `DNET`*`x`* based on your protocol selection. Regardless of which protocol is selected, the number *x* is the only relevant identifier with respect to NI-CAN and NI-DNET functions. For example, if you select **DNET0** as an interface in MAX, you can run an NI-DNET application that uses **DNET0**, then you can run an NI-CAN application that uses **CAN0**. Both applications refer to the same port, and can run at different times, but not simultaneously.

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NI-DNET Hardware Overview

Types of Hardware

The National Instruments DeviceNet hardware includes the PCI-CAN, PXI-8461, and PCMCIA-CAN.

The PCI-CAN is software configurable and compliant with the PCI Local Bus Specification. It features the National Instruments MITE bus interface chip that connects the card to the PCI I/O bus. With a PCI-CAN, you can make your PC-compatible computer with PCI Local Bus slots communicate with and control DeviceNet devices.

The PXI-8461 is software configurable and compliant with the *PXI Specification* and *CompactPCI Specification*. It features the National Instruments MITE bus interface chip that connects the card to the PXI or CompactPCI I/O bus. With a PXI-8461 card, you can make your PXI or CompactPCI chassis communicate with and control DeviceNet devices.

PCMCIA-CAN hardware is a 16-bit, Type II PC Card that is software configurable and compliant with the PCMCIA standards for 16-bit PC cards. With a PCMCIA-CAN card, you can make your PC-compatible notebook with PCMCIA slots communicate with and control DeviceNet devices.

The PCI-CAN, PXI-8461, or PCMCIA-CAN in your DeviceNet kit is fully compliant with the DeviceNet Specification.

All of the DeviceNet hardware uses the Intel 386EX embedded processor to implement time-critical features provided by the NI-DNET software. The cards communicate with the NI-DNET driver through on-board shared memory and an interrupt.

The DeviceNet physical communication link protocol is based on the Controller Area Network (CAN) protocol. The physical layers of the PCI-CAN, PXI-8461, and PCMCIA-CAN fully conform to the DeviceNet physical layer requirements. The physical layer is optically isolated to 500 V and is powered from the DeviceNet bus power supply. DeviceNet interfacing is accomplished using the Intel 82527 CAN controller chip.

For more information on the DeviceNet physical layer and cables used to connect to your DeviceNet devices, refer to Appendix B, *Cabling Requirements*.

For connection to the network, the PCI-CAN, PXI-8461, and PCMCIA-CAN for DeviceNet provide combicon-style pluggable screw terminals, as required by the DeviceNet Specification.

Differences Between CAN Kits and DeviceNet Kits

National Instruments provides hardware/software kits for both CAN and DeviceNet. Since the CAN kits apply to a broad range of applications such as automotive testing, the hardware in those kits offers a wide variety of options. To ensure that the hardware product operates properly on a DeviceNet network, we recommend that you purchase DeviceNet kits only. The card provided in your DeviceNet kit can be used with both NI-DNET and NI-CAN software.

Hardware in CAN kits is referenced as Series 2. Hardware in DeviceNet kits is referenced as Series 1. Series 2 CAN cards cannot be used with the NI-DNET software (NI-CAN only). The features of Series 2 CAN cards are specifically designed for CAN applications, and provide no distinct advantages for DeviceNet. For more information on Series 2 hardware, refer to the hardware overview in the *NI-CAN Hardware and Software Manual*.

Hardware in CAN kits offers 1-port and 2-port variants. NI-DNET operates on one port only. If you use NI-DNET on a 2-port Series 1 CAN card, only the top port can be used.

Hardware in CAN kits offer special transceivers (physical layer) such as Low-Speed/Fault-Tolerant (LS) and Single-Wire (SW). Hardware in CAN kits also offer the option to power the transceiver from the card, not the network. These transceivers cannot be used with DeviceNet. Only High-Speed (HS) transceivers comply with the DeviceNet specification.

Hardware in CAN kits use the DB-9 D-SUB connector. Hardware in DeviceNet kits use the combicon-style connector from the DeviceNet specification.

3 Developing Your Application

This chapter explains how to develop an application using the NI-DNET functions.

Accessing NI-DNET from your Programming Environment

Applications can access the NI-DNET driver software by using either LabVIEW, LabWindows™/CVI™, Microsoft Visual C/C++, Borland C/C++, or Visual Basic. If you are using any other development environment, you must access the DNET library directly. Each of these language interface techniques is summarized below.

LabVIEW

For applications written in LabVIEW, NI-DNET provides a complete function library, front panel controls, and examples.

NI-DNET functions and controls are available in the LabVIEW palettes. In LabVIEW 7.1 or later, the NI-DNET palette is located within the top-level **NI Measurements** palette. In earlier LabVIEW versions, the NI-DNET palette is located at the top-level.

The reference for each NI-DNET function is provided in the *NI-DNET Programmer Reference Manual*. To access the reference for a function from within LabVIEW, press <Ctrl-H> to open the help window, click on the NI-DNET function, and then follow the link.

The NI-DNET software includes a full set of examples for LabVIEW. These examples teach basic NI-DNET programming as well as advanced topics. The example help describes each example and includes a link you can use to open the VI. The NI-DNET example help is in **Help»Find Examples»Hardware Input and Output»DeviceNet**.

LabWindows/CVI

Within LabWindows/CVI, the NI-DNET function panel is located in **Library»NI-DNET**. Like other LabWindows/CVI function panels, the NI-DNET function panel provides help for each function and the ability to generate code.

The reference for each NI-DNET function is provided in the *NI-DNET Programmer Reference Manual*. You can access reference for each function directly from within the function panel.

The header file for NI-DNET is `nidnet.h`. The library for NI-DNET is `nidnet.lib`.

The NI-DNET software includes a full set of examples for LabWindows/CVI. The NI-DNET examples are installed in the `LabWindows/CVI` directory under `samples\nidnet`. Each example provides a complete LabWindows/CVI project (`.prj` file). A description of each example is provided in comments at the top of the `.c` file.

When you compile your LabWindows/CVI application for NI-DNET, it is automatically linked with `nidnet.lib`, the link library for LabWindows/CVI. When NI-DNET is installed, the installation program checks to see which compatible C compiler you are using with LabWindows/CVI (Microsoft or Borland), and copies an appropriate `nidnet.lib` for that compiler.

Microsoft Visual Basic

To create an NI-DNET application in Visual Basic, add the `nidnet.bas` file to your project. This allows you to call any NI-DNET function file from your code.

The `nidnet.bas` file is located in the `MS Visual Basic` folder of the `NI-DNET` folder. The typical path to this folder is `\Program Files\National Instruments\NI-DNET\MS Visual Basic`.

The reference for each NI-DNET function is provided in the *NI-DNET Programmer Reference Manual*, which you can open from **Start»All Programs»National Instruments»NI-DNET**.

You can find examples for Visual Basic in the `examples` subfolder of the `MS Visual Basic` folder. Each example is in a separate folder. A `.vbp` file with the same name as the example opens the Visual Basic project. A description of the example is located in a Help form within the project.

Microsoft C/C++

The NI-DNET software supports Microsoft Visual C/C++ version 6.

The header file and library for Visual C/C++ 6 are in the `MS Visual C` folder of the `NI-DNET` folder. The typical path to this folder is `\Program Files\National Instruments\NI-DNET\MS Visual C`. To use NI-DNET, include the `nidnet.h` header file in your code, then link with the `nidnetms.lib` library file.

For C applications (files with a `.c` extension), include the header file by adding a `#include` to the beginning of your code, as in:

```
#include "nidnet.h"
```

For C++ applications (files with `.cpp` extension), define `_cplusplus` before including the header, such as:

```
#define _cplusplus

#include "nidnet.h"
```

The `_cplusplus` define enables the transition from C++ to the C language NI-DNET functions.

The reference for each NI-DNET function is provided in the *NI-DNET Programmer Reference Manual*, which you can open from **Start»All Programs»National Instruments»NI-DNET**. You can find examples for Visual C++ in the `examples` subfolder of the `MS Visual C` folder. Each example is in a separate folder. A `.c` file with the same name as the example contains a description the example in comments at the top of the code. At the command prompt, after setting MSVC environment variables (such as with MS `vcvars32.bat`), you can build each example using a command such as:

```
cl -I.. singin.c ..\nidnetms.lib
```

Borland C/C++

The NI-DNET software supports Borland C/C++ version 5 or later.

The header file and library for Borland C/C++ are in the **Borland C** folder of the **NI-DNET** folder. The typical path to this folder is `\Program Files\National Instruments\NI-DNET\Borland C`.

To use NI-DNET, include the `nidnet.h` header file in your code, then link with the `nidnetbo.lib` library file.

For C applications (files with `.c` extension), include the header file by adding a `#include` to the beginning of your code, like this:

```
#include "nidnet.h"
```

For C++ applications (files with `.cpp` extension), define `_cplusplus` before including the header, such as:

```
#define _cplusplus

#include "nidnet.h"
```

The `_cplusplus` define enables the transition from C++ to the C language NI-DNET functions.

The reference for each NI-DNET function is provided in the *NI-DNET Programmer Reference Manual*, which you can open from **Start»All Programs»National Instruments»NI-DNET**.

You can find examples for Visual C++ in the `examples` subfolder of the `Borland C` folder. Each example is in a separate folder. A `.c` file with the same name as the example contains a description the example in comments at the top of the code.

Other Programming Languages

You can directly access NI-DNET from any programming environment that allows you to request addresses of functions that a dynamic link library (DLL) exports. The functions used to access a DLL in this manner are provided by the Microsoft Win32 functions of Windows. Using these Microsoft Win32 functions to access a DLL is often referred to as direct entry. To use direct entry with NI-DNET, complete the following steps:

1. Load the NI-DNET DLL, `nican.dll`.

   The following C language code fragment illustrates how to call the Win32 `LoadLibrary` function and check for an error.

   ```
   #include <windows.h>
   #include "nidnet.h"

   HINSTANCE NidnetLib = NULL;

   NidnetLib=LoadLibrary("nican.dll");
   if (NidnetLib == NULL) {
      return FALSE; /*Error*/
   }
   ```

2. Get the addresses for the NI-DNET DLL functions you will use.

   Your application must use the Win32 `GetProcAddress` function to get the addresses of the NI-DNET functions your application needs. For each NI-DNET function used by your application, you must define a direct entry prototype. For the prototypes for each function exported by `nican.dll`, refer to the *NI-DNET Programmer Reference Manual*. The following code fragment illustrates how to get the addresses of the `ncOpenDnetIO`, `ncCloseObject`, and `ncReadDnetIO` functions.

```
static NCTYPE_STATUS (_NCFUNC_ *PncOpenDnetIO)
    (NCTYPE_STRING ObjName,
    NCTYPE_OBJH_P ObjHandlePtr);
static NCTYPE_STATUS (_NCFUNC_ *PncCloseObject)
    (NCTYPE_OBJH ObjHandle);
static NCTYPE_STATUS (_NCFUNC_ *PncReadDnetIO)
    (NCTYPE_OBJH ObjHandle, NCTYPE_UINT32 SizeofData,
    NCTYPE_ANY_P Data);

PncOpenDnetIO = (NCTYPE_STATUS (_NCFUNC_ *)
    (NCTYPE_STRING, NCTYPE_OBJH_P))
    GetProcAddress(NidnetLib,
    (LPCSTR)"ncOpenDnetIO");
PncCloseObject = (NCTYPE_STATUS (_NCFUNC_ *)

    (NCTYPE_OBJH))
    GetProcAddress(NidnetLib,
    (LPCSTR)"ncCloseObject");
PncRead = (NCTYPE_STATUS (_NCFUNC_ *)
    (NCTYPE_OBJH, NCTYPE_UINT32, NCTYPE_ANY_P))
    GetProcAddress(NidnetLib,
    (LPCSTR)"ncReadDnetIO");
```

   If `GetProcAddress` fails, it returns a NULL pointer. The following code fragment illustrates how to verify that none of the calls to `GetProcAddress` failed.

```
if ((PncOpenDnetIO == NULL) ||
        (PncCloseObject  == NULL) ||
        (PncReadDnetIO == NULL)) {
    FreeLibrary(NidnetLib);
    printf("GetProcAddress failed");
}
```

3. Configure your application to de-reference the pointer to call an NI-DNET function, as illustrated by the following code.

   ```
   NCTYPE_STATUS status;
   NCTYPE_OBJH MyObjh;

   status = (*PncOpenDnetIO) ("DNET0", &MyObjh);
   if (status < 0) {
      printf("ncOpenDnetIO failed");
   }
   ```

4. Free `nican.dll`.

   Before exiting your application, you need to free `nican.dll` with the following command.

   ```
   FreeLibrary(NidnetLib);
   ```

Programming Model for NI-DNET Applications

The following steps provide an overview of how to use the NI-DNET functions in your application. The steps are shown in Figure 3-1 in flowchart form. The NI-DNET functions are described in detail in the *NI-DNET Programmer Reference Manual*.

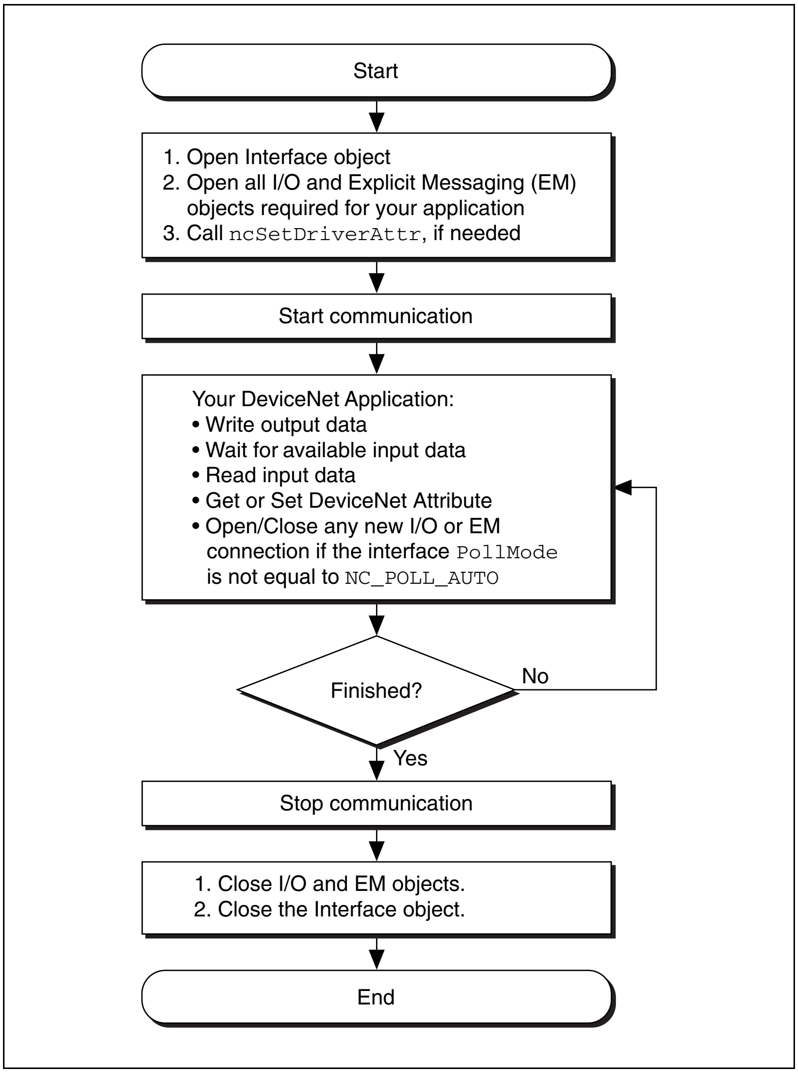

Start
1. Open Interface object
2. Open all I/O and Explicit Messaging (EM) objects required for your application
3. Call ncSetDriverAttr, if needed
Start communication
Your DeviceNet Application:
• Write output data
• Wait for available input data
• Read input data
• Get or Set DeviceNet Attribute
• Open/Close any new I/O or EM connection if the interface PollMode is not equal to NC_POLL_AUTO
Finished?
No
Yes
Stop communication
1. Close I/O and EM objects.
2. Close the Interface object.
End

Figure 3-1. General Programming Steps for an NI-DNET Application

Step 1. Open Objects

Before you use an NI-DNET object in your application, you must configure and open it using either `ncOpenDnetIntf`, `ncOpenDnetExplMsg`, or `ncOpenDnetIO`. These open functions return a handle for use in all subsequent NI-DNET calls for that object.

The `ncOpenDnetIntf` function configures and opens an Interface Object. Your NI-DNET application uses this Interface Object to start and stop communication. The Interface Object must be the first NI-DNET object opened by your application.

The `ncOpenDnetExplMsg` function configures and opens an Explicit Messaging Object, and the `ncOpenDnetIO` function configures and opens an I/O Object.

Step 2. Start Communication

Start communication to initialize DeviceNet connections to remote devices. Use the Interface Object to call the `ncOperateDnetIntf` function with the `Opcode` parameter set to `Start`.

The following optional steps can be done before you start communication:

- For an I/O Object, if it is not acceptable to send output data of all zeros, call `ncWriteDnetIO` to provide valid output values for the initial transmission.
- For an I/O Object, if your application is multitasking, call the `ncCreateNotification` or `ncCreateOccurrence` function with the `DesiredState` parameter set to `Read Available`. This notifies your application when new input data is received from the remote device.
- For any NI-DNET object, if any of the Driver attributes needs to be changed, call `ncSetDriverAttr` with the attribute Id and attribute value. The `ncSetDriverAttr` function cannot be called after the communication has started.

Step 3. Run Your DeviceNet Application

After you open your NI-DNET objects and start communication, you are ready to interact with the DeviceNet network.

Complete the following steps with an I/O Object:

1. Call the `ncWriteDnetIO` function to write output data for subsequent transmission on the DeviceNet network.

2. Call the `ncWaitForState` function with the `DesiredState` parameter set to `Read Available`. This function waits for output data to be transmitted and for new input data to be received. If your application is multitasking, you might have other tasks to do in your application while you wait for new input data. If so, use the `ncCreateNotification` or `ncCreateOccurrence` function instead of `ncWaitForState` (refer to *Step 2. Start Communication*).
3. Call the `ncReadDnetIO` function to read input data received from the DeviceNet network.
4. Loop back to step 1 as needed.

Complete the following steps with an Explicit Messaging Object:

1. Call the `ncWaitForState` function with the `DesiredState` parameter set to `Established`. This ensures that the explicit message connection is established before you send the first explicit message request.
2. To get an attribute from a remote DeviceNet device, call the `ncGetDnetAttribute` function.
3. To set the value of an attribute in a remote DeviceNet device, call the `ncSetDnetAttribute` function.
4. To invoke other explicit message services in a remote DeviceNet device, use the `ncWriteDnetExplMsg` function to write the service request, the `ncWaitForState` function to wait for the service response, and the `ncReadDnetExplMsg` function to read the service response.
5. Loop back to step 2 as needed.

Addition of Slave Connections after Communication Start

If you need to add I/O and Explicit Messaging connections after the communication on the network has started, you can call `ncOpenDnetExplMsg` and `ncOpenDnetIO` as long as the Interface Object's poll mode had been configured to `NC_POLL_SCAN` (Scanned) or `NC_POLL_INDIV` (Individual). Since the Automatic poll mode (`NC_POLL_AUTO`) calculates the expected packet rate (EPR) based on the estimated network bandwidth, all the I/O connections have to be opened before you start the communication if the Automatic mode is selected. The EPR restrictions due to different values of the `PollMode` parameter still apply to the I/O objects. For details on these requirements, refer to `ncOpenDnetIO` and `ncOpenDnetIntf` function descriptions in the *NI-DNET Programmer Reference Manual*.

Step 4. Stop Communication

Before you exit your application, stop communication to shut down DeviceNet connections to remote devices. Use the Interface Object to call the `ncOperateDnetIntf` function with the `Opcode` parameter set to `Stop`.

Step 5. Close Objects

Before you exit your application, close all NI-DNET objects using the `ncCloseObject` function.

Multiple Applications on the Same Interface

The NI-DNET software allows multiple NI-DNET applications to use the same interface object simultaneously, as long as the interface configuration remains the same. For example, you can run both the `SingleDevice` example and **SimpleWho** on **DNET0** as long as the `Interface MacId`, `BaudRate`, and `PollMode` parameters are the same in both applications (**SimpleWho** uses a `PollMode` of `Scanned`). Similarly, you can open up two copies of the `SingleDevice` example and communicate with two different devices as if it were through a single application. These same rules apply to the I/O Object and the Explicit Messaging Object.

As long as all the configuration attributes are the same, any object can be opened multiple times. You can enable only one notification or wait (through `ncWaitForState`, `ncCreateNotification`, or `ncCreateOccurrence` functions) for an object, no matter how many handles you have opened for that particular object. For example, if you are running two copies of the `SingleDevice` example on the same interface with the same connection types, the notification triggers in only one application at a time.

The synchronization of events and the protection of the object I/O data is the responsibility of the application developer. Similarly, the application performance might change based on the number of objects open and the frequency of API calls made in each application. For example, several calls to `ncGetDnetAttribute` in one application might slow down another application running on the same interface.

To ensure proper clean up of all the objects, each open call to an object should be matched by a close call to the same object, and each call to `ncOperateDnetIntf` with `NC_OP_START` code should be matched by a call to the same function with `NC_OP_STOP` code.

If you use two different applications on the same interface and open I/O connections to different devices, you must set `PollMode` to either `Scanned` or `Individual`. You cannot use `PollMode` of `Automatic`, because that requires all I/O connections to be open prior to the first start of communication.

Checking Status in LabVIEW

For applications written in LabVIEW, status checking is handled automatically. For all NI-DNET functions, the lower left and right terminals provide status information using LabVIEW Error Clusters. LabVIEW Error Clusters are designed so that status information flows from one function to the next, and function execution stops when an error occurs. For more information, refer to the Error Handling section in the LabVIEW online reference.

Within your LabVIEW block diagram, you wire the `Error in` and `Error out` terminals of NI-DNET functions together in succession. When an error is detected in an NI-DNET function (`status` field true), all NI-DNET functions wired together are skipped except for `ncCloseObject`. The `ncCloseObject` function executes regardless of whether an error occurred, thus ensuring that all NI-DNET objects are closed properly when execution stops due to an error. Depending on how you want to handle errors, you can wire the `Error in` and `Error out` terminals together per-object (group a single open/close pair), per-device (group together Explicit Messaging and I/O Objects for a given device), or per-network (group all functions for a given interface).

As with any other LabVIEW error cluster, you can view error descriptions using built-in LabVIEW features such as **Explain Error** in the **Help** menu, or the **Simple Error Handler VI** in your diagram.

Checking Status in C, C++, and Visual Basic

Each C language NI-DNET function returns a value that indicates the status of the function call. This status value is zero for success, greater than zero for a warning, and less than zero for an error.

After every call to an NI-DNET function, your program should check to see if the return status is nonzero. If so, call the `ncStatusToString` function to obtain an ASCII string which describes the error/warning. You can then use standard C function, such as `printf`, to display this ASCII string.

Your application code should check the status returned from every NI-DNET function. If an error is detected, you should close all NI-DNET handles, then exit the application. If a warning is detected, you can display a message for debugging purposes, or simply ignore the warning.

For more information on status checking, refer to the `ncStatusToString` function in the *NI-DNET Programmer Reference Manual*.

4 NI-DNET Programming Techniques

This chapter describes various techniques to help you program your NI-DNET application. The techniques include configuration of I/O connection timing, using I/O data (assemblies), using explicit messaging, and handling multiple devices.

Configuring I/O Connections

This section provides information on how I/O connections relate to one another and how your configuration of I/O connection timing can affect the overall performance of your DeviceNet system. The various types of I/O connections provided by DeviceNet are described in Chapter 1, *NI-DNET Software Overview*.

In a master/slave DeviceNet I/O system, the master determines the timing of all I/O communication. Within your NI-DNET application, the `ncOpenDnetIO` function configures the timing for I/O connections in which your application communicates as master. As you read this section, you might want to refer to the description of the `ncOpenDnetIO` function in the *NI-DNET Programmer Reference Manual*.

Expected Packet Rate

Each DeviceNet I/O connection contains an attribute called the expected packet rate, which specifies the expected rate (in milliseconds) of messages (*packets*) for the I/O connection. For NI-DNET, you use the `ExpPacketRate` parameter of the `ncOpenDnetIO` function to configure the expected packet rate.

After you start communication, the embedded microprocessor on your National Instruments DeviceNet interface transmits messages at the `ExpPacketRate`. This means that after the I/O connection is configured, your NI-DNET application does not need to be concerned with the timing of messages on the DeviceNet network.

When you select an `ExpPacketRate` for an I/O connection, you must consider all I/O connections in your system. For example, although you might be able to configure an `ExpPacketRate` of 3 ms for a single I/O connection, you cannot configure a 3 ms `ExpPacketRate` for 40 I/O connections because DeviceNet's bandwidth capabilities cannot support 40 messages in a 3 ms time frame.

The following sections describe how to evaluate system considerations so that you can configure valid values for `ExpPacketRate`.

Strobed I/O

For strobed I/O connections, the master broadcasts a single strobe command message to all strobed slaves. Since all strobed I/O connections transfer data at the rate of this single strobe command message, the `ExpPacketRate` of each strobed I/O connection must be set to the same value.

The common `ExpPacketRate` for all strobed I/O connections should provide enough time for the strobe command and each strobed slave's response. You must also allow time for other I/O messages and explicit messages to occur in the `ExpPacketRate` time frame. If you do not know the time needed, let NI-DNET calculate a safe value for you (refer to the section *Automatic EPR Feature* later in this chapter).

Figure 4-1 shows a timing example for four strobed devices at MAC ID 9, 11, 12, and 13. Notice that since MAC ID 11 is slow to respond, the `ExpPacketRate` is set to 20 ms to provide additional safety margin for other messages.

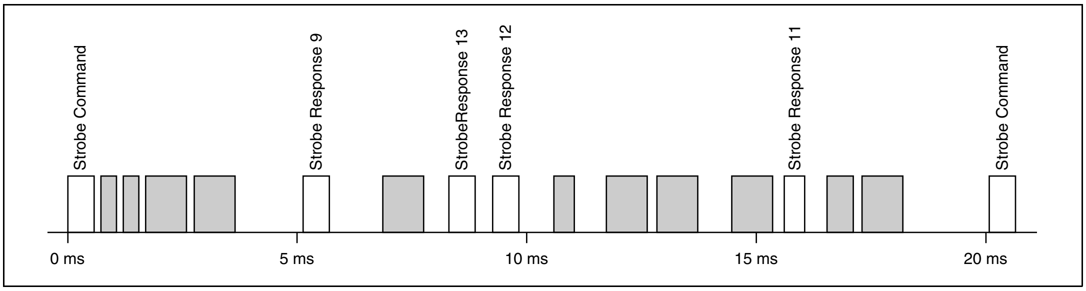


Figure 4-1. Strobed I/O Timing Example

Polled I/O

Polled I/O connections use a separate poll command and response message for each device.

The overall scheme that NI-DNET uses to time polled I/O connections is determined by the `PollMode` parameter of `ncOpenDnetIntf`. This `PollMode` parameter applies to all polled I/O connections (all calls to `ncOpenDnetIO` with `ConnectionType` of `Poll`).

The following sections describe different schemes you can use for polled I/O.

Scanned Polling

You can set the `ExpPacketRate` of each polled I/O connection to the same value used for all strobed I/O. Using a common `ExpPacketRate` for all strobed and polled I/O is referred to as scanned I/O. Scanned I/O is also referred to as scanned polling with respect to polled I/O connections. When you use scanned I/O, NI-DNET transmits all strobe and poll command messages onto the network in quick succession.

Scanned I/O is a simple, efficient way to handle I/O connections that require similar response rates. With scanned I/O, the master knows that all strobe and poll commands go out at the same time. Therefore, the master does not need to manage individual timers, thus optimizing processing overhead. Scanned I/O also provides overall consistency. If a given DeviceNet system uses only scanned I/O, you know that all higher level control algorithms can execute at the single common strobe/poll `ExpPacketRate`.

The common `ExpPacketRate` for all strobed and polled I/O connections should provide enough time for all strobe/poll commands and each slave's response. You must also allow time for other I/O messages and explicit messages to occur in the `ExpPacketRate` time frame.

NI-DNET provides two different methods you can use to configure scanned I/O:

- If you set the `PollMode` parameter of `ncOpenDnetIntf` to `Automatic`, NI-DNET automatically calculates a valid common `ExpPacketRate` value for each strobed and polled I/O connection. When you use this scheme, you do not need to specify a valid `ExpPacketRate` when you open your strobed/polled I/O connections. For more information, refer to the *Automatic EPR Feature* section later in this chapter.

- If you set the `PollMode` parameter of `ncOpenDnetIntf` to `Scanned`, to configure scanned I/O you must specify the exact same `ExpPacketRate` when you open each of your strobed/polled I/O connections. Using this scheme, you must determine a valid `ExpPacketRate` for your DeviceNet system.

Figure 4-2 shows a scanned polling example for four polled devices at MAC ID 14, 17, 20, and 30. The shaded areas indicate other message traffic, such as the strobed I/O messages shown in Figure 4-1.

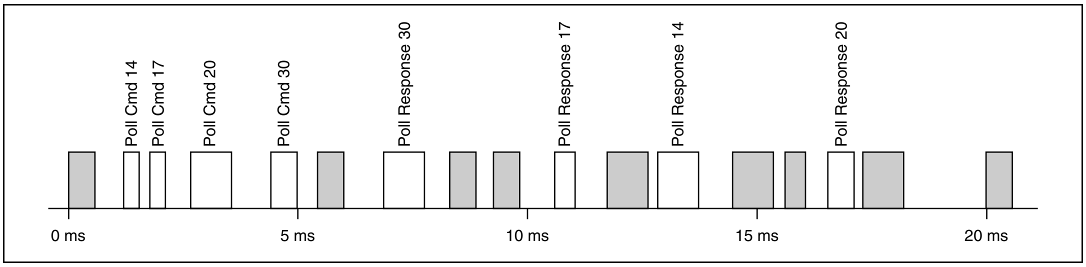


Figure 4-2. Scanned Polling Timing Example

Background Polling

Scanned polling can be less efficient when used with devices with significantly different response times or devices with significantly different rates of physical measurement. In the example above (Figure 4-2), consider what would happen if device 14 took 52 ms to respond and device 20 took 38 ms to respond. In this case, even though device 17 and device 30 respond well within 20 ms, the common `ExpPacketRate` would need to be at least 52 ms. This situation can often be avoided using a special case of scanned polling called *background polling*.

To configure background polling, you first set the `PollMode` parameter of `ncOpenDnetIntf` to `Scanned`. Then for each polled I/O connection you configure (`ncOpenDnetIO` with `ConnectionType` set to `Poll`), you must set `ExpPacketRate` to either a foreground rate or a background rate. The foreground poll rate is the same as the common `ExpPacketRate` used for all strobed I/O. Devices in this group generally respond quickly to poll commands or have data that changes relatively quickly. The background poll rate must be an exact multiple of the foreground poll rate. Devices in this group generally respond slowly to poll commands or have data that changes relatively slowly (such as temperature).

Background polling provides many of the same advantages as scanned polling. The handling of only two groups optimizes performance. Also, background polling maintains overall network consistency because NI-DNET evenly disperses all background poll commands among multiple foreground cycles. In other words, all background poll commands are not sent in quick succession and thus do not generate quick bursts of traffic on the network.

Figure 4-3 shows a background polling example which resolves the problem discussed previously. Devices at MAC ID 17 and 30 are foreground polled every 20 ms (as before). Devices at MAC ID 14 and 20 are background polled every 60 ms (3 times the 20 ms foreground rate). The shaded areas indicate other message traffic.

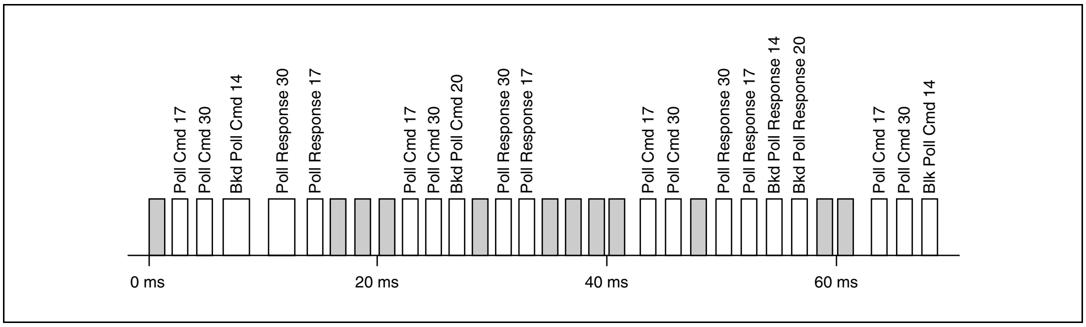


Figure 4-3. Background Polling Timing Example

Individual Polling

When the underlying response rates of all polled I/O devices do not fit into two clear groups, background polling can still be inefficient. For example, assume you have four different polled I/O sensors capable of updating measured input at 10 ms, 35 ms, 100 ms, and 700 ms respectively. Each device responds to its poll command within 1 ms but measures data at a different rate (such as a pushbutton for 10 ms and a temperature sensor for 700 ms). You could group these into a foreground rate of 10 ms and a background rate of 700 ms, but then much DeviceNet bandwidth would be wasted polling the 35 ms and 100 ms devices at the foreground rate. For this situation, the *individual polling* scheme is most appropriate.

To configure individual polling, first set the `PollMode` parameter of `ncOpenDnetIntf` to `Individual`. Then for each polled I/O connection you configure (`ncOpenDnetIO` with `ConnectionType` set to `Poll`), you must set `ExpPacketRate` to the rate desired for that device. Unlike the scanned polling or background polling scheme, each poll command is no longer associated with the strobe command's rate, but instead is solely based on its `ExpPacketRate`.

Since the poll commands are not synchronized for individual polling, they can often be scattered relatively randomly. They can be evenly interspersed for a while, then suddenly occur in bursts of back-to-back messages. Because of this inconsistency, you should use smaller MAC IDs for smaller `ExpPacketRate` values. Since smaller MAC IDs in DeviceNet usually gain access to the network before larger MAC IDs, this helps to ensure that smaller rates can be maintained during bursts of increased traffic.

Figure 4-4 shows an individual polling example: MAC ID 3 is polled every 10 ms, MAC ID 10 every 35 ms, MAC ID 12 every 100 ms, and MAC ID 13 every 700 ms. Only the poll commands are shown (not poll responses or other messages).

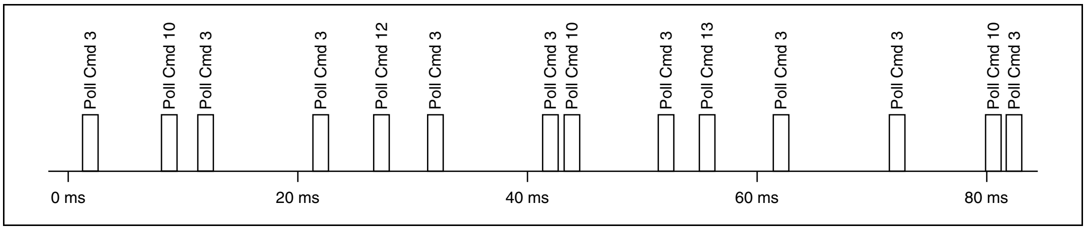


Figure 4-4. Individual Polling Timing Example

Cyclic I/O

Cyclic I/O connections essentially use the same timing scheme as individually polled I/O connections. Each cyclic I/O connection sends its data at the configured `ExpPacketRate`. The main difference is that cyclic I/O data is transferred from slave to master, rather than from master to slave.

In the DeviceNet Specification, a poll command message is exactly the same as a cyclic output message (master to slave data). Since cyclic data from master to slave can be handled using individual polling, cyclic I/O connections are more commonly used for input data from slave to master. For NI-DNET, this means that for cyclic I/O connections, `ncOpenDnetIO` is normally called with `InputLength` nonzero and `OutputLength` zero.

Just as for individually polled I/O, you should use smaller MAC IDs for smaller cyclic I/O `ExpPacketRate` values. Doing so ensures that cyclic I/O traffic is prioritized properly.

Change-of-State (COS) I/O

Change-of-State I/O connections use the same timing scheme as cyclic I/O connections, but in addition to the `ExpPacketRate`, COS I/O sends data to the master whenever a change is detected.

For COS I/O, the cyclic transmission is used solely to verify that the I/O connection still exists, so the `ExpPacketRate` is typically set to a large value, such as 10,000 (10 seconds). Given such a large `ExpPacketRate`, the main performance concerns for COS I/O are an appropriate MAC ID, and if needed, a nonzero `InhibitTimer`.

In many cases, a given COS I/O device cannot detect data changes very quickly. If a COS device is capable of detecting quickly changing data, there is a chance that it could transmit many COS messages back-to-back, precluding other I/O messages and thus dramatically impairing overall DeviceNet performance. This problem is demonstrated in Figure 4-5.

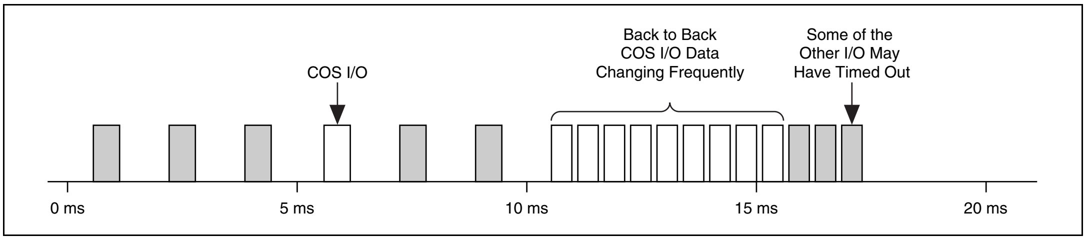


Figure 4-5. Congestion Due to Back-to-Back COS I/O

This problem can be prevented if you increase the MAC ID of the frequently changing COS I/O device. If the COS device has a higher MAC ID than other devices, it cannot preclude their I/O messages.

You can also prevent back-to-back COS I/O messages if you set the `InhibitTimer` driver attribute using `ncSetDriverAttr`. After transmitting COS data, the I/O connection must wait `InhibitTimer` before it can transmit COS data again. A reasonable value for `InhibitTimer` would be the smallest `ExpPacketRate` of an I/O connection with a larger MAC ID than the COS I/O device.

Automatic EPR Feature

For cyclic I/O connections, a valid `ExpPacketRate` is required for your call to `ncOpenDnetIO`. For COS I/O connections, a nonzero `ExpPacketRate` is recommended for your call to `ncOpenDnetIO` but can be set to a large value.

For strobed and polled I/O connections, determination of a valid `ExpPacketRate` can be somewhat complex. If you have trouble estimating an `ExpPacketRate` value for strobed/polled I/O, set the `PollMode` parameter of your initial call to `ncOpenDnetIntf` to `Automatic`. When you use this automatic EPR feature, the `ExpPacketRate` parameter of `ncOpenDnetIO` is ignored for strobed/polled I/O (`ConnectionType` of `Strobe` or `Poll`), and NI-DNET calculates a safe EPR value for you. This automatic EPR is the same for all strobed and polled I/O connections (scanned I/O).

After you start communication, you can use the `ncGetDriverAttr` function to determine the value calculated for `ExpPacketRate`. From that value, you can then experiment with other `ExpPacketRate` configurations using `PollMode` of `Scanned` or `Individual`.

The following information is used by NI-DNET to calculate a safe EPR:

- NI-DNET assumes that it is the only master in your DeviceNet system.
- The `BaudRate` parameter of `ncOpenDnetIntf` determines the time taken for each message.
- The `InputLength` and `OutputLength` parameters of each `ncOpenDnetIO` determine the time needed for each I/O message.
- NI-DNET assumes that each strobed/polled I/O device can respond to its command within 2 ms.
- NI-DNET sets aside a fixed amount of time for explicit messages. This time depends on the baud rate.

Using I/O Data in Your Application

Appendix A, *DeviceNet Overview*, explains that the data transferred to and from a DeviceNet device on an I/O connection is usually processed by an Assembly Object within the slave device. Input assemblies represent the data received by NI-DNET from a remote device, and output assemblies represent data that NI-DNET transmits to a remote device.

To use a device’s I/O data within your application, you need to understand the contents of its input and output assemblies. You can find this information in the following places:

- Printed documentation provided by the device’s vendor.
- If the device conforms to a standard device profile, the I/O assemblies are defined within the DeviceNet Specification.

- Some device vendors provide comments about I/O assemblies in an Electronic Data Sheet (EDS). The EDS file is a text file whose format is defined by the DeviceNet Specification.
- Ask the device's vendor if they have filled out a DeviceNet compliance statement. This form is located at the front of the DeviceNet Specification, and it provides information about the device, including its I/O assemblies.

After you open an NI-DNET I/O Object and start communication, you use the `ncWriteDnetIO` function to write an output assembly for a device and the `ncReadDnetIO` function to read an input assembly received from a remote device. Both of these functions access the entire assembly as an array of bytes.

In most cases, the array of bytes for an input or output assembly contains more than one value. In DeviceNet terminology, an individual data value within an I/O assembly is referred to as a *member*.

Documentation for the members of an input or output assembly includes the position of each member in the assembly (often shown as a table with byte/bit offsets) and a listing of the attribute in the device that each member represents (often shown as class, instance, and attribute identifiers). For standard device profiles, the I/O assemblies are documented in the device profile's specification, and the actual attributes are documented in the individual object specifications. Attribute documentation includes the attribute's DeviceNet data type and a complete explanation of its meaning.

As an example of I/O assembly documentation, consider the standard AC Drive device profile. For this device profile, the DeviceNet Specification defines an output assembly called Basic Speed Control Output (Assembly Object instance 20). This output assembly is used to start/stop forward motion at a given speed and to reset faults in the device. The bytes of this output assembly are shown in Figure 4-6, and the attribute mapping is shown in Table 4-1.

Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	0	Fault Reset	0	Run Fwd
1	0	0	0	0	0	0	0	0
2	Speed Reference (Low Byte)							
3	Speed Reference (High Byte)							

Figure 4-6. AC Drive Output Assembly, Instance 20

Table 4-1. Attribute Mapping for Basic Speed Control Output Assembly

Member Name	Class Name	Class ID	Instance ID	Attribute Name	Attribute ID
Run Fwd	Control Supervisor	29 hex	1	Run1	3
Fault Reset	Control Supervisor	29 hex	1	FaultRst	12
Speed Reference	AC/DC Drive	2A hex	1	SpeedRef	8

By consulting the specifications for the Control Supervisor object and the AC/DC Drive object, you can determine that the DeviceNet data type for Run Fwd and Fault Reset is `BOOL` (boolean), and the DeviceNet data type for Speed Reference is `INT` (16-bit signed integer).

Accessing I/O Members in LabVIEW

Many fundamental differences exist between the encoding of a DeviceNet data type and its equivalent data type in LabVIEW. For example, for a 32-bit integer, the DeviceNet `DINT` data type uses Intel byte ordering (lowest byte first), and the equivalent LabVIEW `I32` data type uses Motorola byte ordering (highest byte first).

To make it easier for you to avoid these data type issues in your LabVIEW application, NI-DNET provides two functions to convert between LabVIEW data types and DeviceNet data types: `ncConvertForDnetWrite` and `ncConvertFromDnetRead`. These functions are used to access individual members of an I/O assembly using normal LabVIEW controls and indicators.

The following steps show an example of how you can use `ncConvertForDnetWrite` to access the Basic Speed Control Output Assembly described in the previous section:

1. Use the NI-DNET palette to place `ncConvertForDnetWrite` into your diagram.
2. Right-click on the `DnetData in` terminal and select **Create Constant**, then initialize the first 4 bytes of the array to zero.
3. Right-click on the `DnetType` terminal and select **Create Constant**, then select `BOOL` from the enumeration.

4. Right-click on the `ByteOffset` terminal and select **Create Constant**, then enter `0` as the byte offset.
5. Right-click on the `8[TF] in` terminal and select **Create Control**. In the front panel control that appears, you can use the button at index 0 to control Run Fwd and the button at index 2 to control Fault Reset.
6. Using the NI-DNET palette, place `ncConvertForDnetWrite` into your diagram.
7. Wire the `DnetData out` terminal from the previous `Convert` into the `DnetData in` terminal of this `Convert`.
8. Right-click on the `DnetType` terminal and select **Create Constant**, then select `INT` from the enumeration.
9. Right-click on the `ByteOffset` terminal and select **Create Constant**, then enter `2` as the byte offset.
10. Right-click on the `I32/I16/I8 in` terminal and select **Create Control**. You can use the front panel control that appears to change Speed Reference.
11. Using the NI-DNET palette, place `ncWriteDnetIO` into your diagram.
12. Wire the `DnetData out` terminal from the previous `Convert` into the `Data` terminal of `ncWriteDnetIO`.

For more information on the `ncConvertForDnetWrite` and `ncConvertFromDnetRead` functions, refer to the *NI-DNET Programmer Reference Manual*. For information on LabVIEW data types and their equivalent DeviceNet data types, refer to Chapter 1, *NI-DNET Data Types*, in the *NI-DNET Programmer Reference Manual*.

Accessing I/O Members in C

Since DeviceNet data types are very similar to C language data types, individual I/O members can be accessed in a straightforward manner. You can use the standard C language pointer manipulations to convert between C language data types and DeviceNet data types.

The following steps show an example of how standard C language can be used to access the Basic Speed Control Output Assembly described in the previous section.

1. Declare an array of 4 bytes, as in the following.

```
NCTYPE_UINT8OutputAsm[4];
```

2. Initialize the array to all zero.

   ```
   for (I = 0; I < 4; I++)
       OutputAsm [I] = 0;
   ```

3. Assume you have two boolean variables, `RunFwd` and `ResetFault`, of type `NCTYPE_BOOL`. For LabWindows/CVI, these variables could be accessed from front panel buttons. The following code inserts these boolean variables into `OutputAsm`.

   ```
   if (RunFwd)
       OutputAsm [0] |= 0x01;
   if (FaultReset)
       OutputAsm [0] |= 0x04;
   ```

4. Assume you have an integer variable `SpeedRef` of type `NCTYPE_INT16`. For LabWindows/CVI, this variable could be accessed from a front panel control. The following code inserts this integer variable into `OutputAsm`.

   ```
   *(NCTYPE_INT16 *)(&( OutputAsm[2])) = SpeedRef;
   ```

5. Write the output assembly to the remote device.

   ```
   status = ncWriteDnetIO(objh, sizeof(OutputAsm),
   OutputAsm);
   ```

For information on NI-DNET's C language data types and their equivalent DeviceNet data types, refer to Chapter 1, *NI-DNET Data Types*, of the *NI-DNET Programmer Reference Manual*.

Using Explicit Messaging Services

The NI-DNET Explicit Messaging Object represents an explicit messaging connection to a remote DeviceNet device. You use `ncOpenDnetExplMsg` to configure and open an NI-DNET Explicit Messaging Object.

The following sections describe how to use the Explicit Messaging Object.

Get and Set Attributes in a Remote DeviceNet Device

The two most commonly used DeviceNet explicit messages are the Get Attribute Single service and the Set Attribute Single service. These services are used to get or set the value of an attribute contained in a remote device. The easiest way to execute the Get Attribute Single service on a remote device is to use the NI-DNET `ncGetDnetAttribute` function. The easiest way to execute the Set Attribute Single service on a remote device is to use the NI-DNET `ncSetDnetAttribute` function.

For a given attribute of a DeviceNet device, you need the following information to use the `ncGetDnetAttribute` or `ncSetDnetAttribute` function:

- The class and instance identifiers for the object in which the attribute is located
- The attribute identifier
- The attribute's DeviceNet data type

You can normally find this information from the object specifications contained in the DeviceNet Specification, but many DeviceNet device vendors also provide this information in the device's documentation.

For the C programming language, the attribute's DeviceNet data type determines the corresponding NI-DNET data type you use to declare a variable for the attribute's value. For example, if the attribute's DeviceNet data type is `INT` (16-bit signed integer), you should declare a C language variable of type `NCTYPE_INT16`, then pass the address of that variable as the `Attr` parameter of the `ncGetDnetAttribute` or `ncSetDnetAttribute` function.

For LabVIEW, the attribute's DeviceNet data type determines the corresponding LabVIEW data type to use with the `ncConvertForDnetWrite` or `ncConvertFromDnetRead` functions. The `ncConvertFromDnetRead` function converts a DeviceNet attribute read using `ncGetDnetAttribute` into an appropriate LabVIEW data type. The `ncConvertForDnetWrite` function converts a LabVIEW data type into an appropriate DeviceNet attribute to write using `ncSetDnetAttribute`. For more information on these LabVIEW conversion functions, refer to the *Using I/O Data in Your Application* section.

Other Explicit Messaging Services

To execute services other than Get Attribute Single and Set Attribute Single, use the following sequence of function calls: `ncWriteDnetExplMsg`, `ncWaitForState`, `ncReadDnetExplMsg`. The `ncWriteDnetExplMsg` function sends an explicit message request to a remote DeviceNet device. The `ncWaitForState` function waits for the explicit message response, and the `ncReadDnetExplMsg` function reads that response.

Use `ncWriteDnetExplMsg` for such DeviceNet services as Reset, Save, Restore, Get Attributes All, and Set Attributes All. Although the DeviceNet

Specification defines the overall format of these services, in most cases their meaning and service data are object-specific or vendor-specific. Unless your device requires such services and documents them in detail, you probably do not need them for your application.

You need the following information to use the `ncWriteDnetExplMsg` and `ncReadDnetExplMsg` functions for a given explicit messaging service:

- The class and instance identifiers for the object to which the service will be directed.
- The service code used to identify the service.
- The length and format of service request and response data. Some of data formats are defined by the service's overall specification (such as in Appendix G, *DeviceNet Explicit Services*, in the *DeviceNet Specification* manual), but many data formats are object-specific or vendor-specific. For example, for the Reset service, Appendix G defines the service's code for use with any object, but its actual data format is defined in the specification for the Identity Object.
- The error codes that can be returned in the service response. Error codes that are common to all services can be found in Appendix H, *DeviceNet Error Codes*, in the *DeviceNet Specification* manual, but many error codes are specific to the service, object, or vendor.

As with the `ncGetDnetAttribute` and `ncSetDnetAttribute` functions, the service data formats for the request and response are specified in terms of DeviceNet data types. These DeviceNet data types are converted to/from the data types of your programming environment (C or LabVIEW) as discussed in previous sections.

Handling Multiple Devices

This section describes techniques you can use to efficiently implement an application that communicates with a large number of DeviceNet devices. In such an application, there might be only one call to `ncOpenDnetIntf` (only one network), but there are usually multiple calls to `ncOpenDnetIO` (and possibly `ncOpenDnetExplMsg`).

Configuration

If the configuration parameters used with `ncOpenDnetIO` tend to change over time, you might want to organize them in data structures instead of using constants.

For the C programming language, you can declare a structure `typedef` to store the parameters of `ncOpenDnetIO`, similar to the following:

```
typedef struct {
    NCTYPE_UINT32DeviceMacId;
    NCTYPE_CONN_TYPEConnectionType;
    NCTYPE_UINT32InputLength;
    NCTYPE_UINT32OutputLength;
    NCTYPE_UINT32ExpPacketRate;
    } OpenDnetIO_Struct;
```

For LabVIEW, a cluster that contains these parameters is already defined for use with `ncOpenDnetIO`.

You can use this structure/cluster to declare an array that contains one entry for each call you make to `ncOpenDnetIO`. In LabVIEW and LabWindows/CVI, you can use front panel controls to index through this array and update configurations as needed.

In your code, write a For loop to index through the array and call `ncOpenDnetIO` once for each array entry. This simplifies your code because it does not contain a long list of sequential open calls, but instead all open calls are combined into a concise loop.

Object Handles

If you use an array to store configuration parameters for `ncOpenDnetIO`, you can use this same scheme to store the `ObjHandle` returned by `ncOpenDnetIO`. Within the For loop used for `ncOpenDnetIO`, you can store the resulting `ObjHandle` into an array of object handles. Throughout your code, you can index into this array to obtain the appropriate object handle.

Using an array of object handles is particularly useful in the LabVIEW programming environment because it eliminates confusing routing of individual object handle wires.

For applications with only a few object handles, another useful technique for LabVIEW is to store each object handle in an indicator, then create a local variable for each call that uses the handle. To create the indicator, right-click on the `ObjHandle out` terminal and select **Create Indicator**. To create a local variable, right-click on the indicator, select **Create»Local Variable**, right-click on the local variable, and select **Change To Read Local**. For more information on local variables, refer to the LabVIEW online reference.

Main Loop

If your application essentially accesses all DeviceNet input/output data as a single image, you would normally wait for read data to become available on one of the input connections (such as a strobed I/O connection), read all input data, execute your application code, then write all output data. The wait is important because it helps to synchronize your application with the overall DeviceNet network traffic.

In single-loop applications such as this, you normally set the `PollMode` parameter of `ncOpenDnetIntf` to `Automatic` or `Scanned` so that all poll command messages are sent out in quick succession.

Within a single-loop application, error handling is often done for the entire application as a whole. In the C programming language, this means that when an error is detected with any NI-DNET object, you display the error and exit the application. In LabVIEW, this means that you wire all error clusters of NI-DNET VIs together.

If your application uses different control code for different DeviceNet devices, you might want to split your application into multiple tasks. You can easily write a multitasking application by creating a notification for the NI-DNET `Read Avail` state. This notification occurs when either input data is available (to synchronize your code with each device's I/O messages), or an error occurs. In the C programming language, you create this notification callback using the `ncCreateNotification` function. In LabVIEW, you create this notification callback using the `ncCreateOccurrence` function.

In multiple-loop applications such as this, you normally set the `PollMode` parameter of `ncOpenDnetIntf` to `Individual` so that each poll command message can be sent out at its own individual rate.

Within a multiple-loop application, error handling is done separately for each task. In the C programming language, this means that when an error is detected, you handle it for the appropriate task, but you do not exit the application. In LabVIEW, this means that you only wire the error clusters of NI-DNET VIs that apply to each task, and thus you write different sub-diagrams that are not wired together in any way.

A

DeviceNet Overview

This appendix gives an overview of DeviceNet.

History of DeviceNet

The Controller Area Network (CAN) was developed in the early 1980s by Bosch, a leading automotive equipment supplier. CAN was developed to overcome the limitations of conventional automotive wiring harnesses. CAN connects devices such as engine controllers, anti-lock brake controllers, and various sensors and actuators on a common serial bus. By using a common pair of signal wires, any device on a CAN network can communicate with any other device.

As CAN implementations became widespread throughout the automotive industry, CAN was standardized internationally as ISO 11898, and major semiconductor manufacturers such as Intel, Motorola, and Philips began producing CAN chips. With these developments, many manufacturers of industrial automation equipment began to consider other applications of CAN technology. Automotive and industrial device networks showed many similarities, including the transition away from dedicated signal lines, low cost, resistance to harsh environments, and excellent real-time capabilities.

In response to these similarities, Allen-Bradley developed DeviceNet, an industrial networking protocol based on CAN. DeviceNet built on CAN's communication facilities to provide higher-level features which allow industrial devices from different vendors to operate on the same network.

Soon after DeviceNet was developed, Allen-Bradley transferred the specification to an independent organization called the Open DeviceNet Vendor's Association (ODVA). ODVA formally manages the *DeviceNet Specification* and provides services to facilitate development of DeviceNet devices and tools by various vendors. Due in large part to the efforts of ODVA, hundreds of different vendors now provide DeviceNet products for a wide range of applications.

Physical Characteristics of DeviceNet

The following list summarizes the physical characteristics of DeviceNet.

- Trunkline-dropline cabling—main trunk cable with a drop cable for each device
- Selectable baud rates of 125 K, 250 K, and 500 K

Table A-1. DeviceNet Baud Rates and Wiring Lengths

Baud Rate	Trunk Length	Drop Length Maximum	Drop Length Cumulative
125 Kb/s	500 m (1640 ft)	6 m (20 ft)	156 m (512 ft)
250 Kb/s	250 m (820 ft)	6 m (20 ft)	78 m (256 ft)
500 Kb/s	100 m (328 ft)	6 m (20 ft)	39 m (128 ft)

- Support for up to 64 devices—each device identifies itself using a MAC ID (Media Access Control Identifier) from 0–63
- Device removal/insertion without severing the network
- Simultaneous support for both network-powered and self-powered devices
- Various connector styles

For complete information on how to connect your National Instruments hardware onto the DeviceNet network, refer to your getting started manual.

General Object Modeling Concepts

The *DeviceNet Specification* uses object-oriented modeling to describe the behavior of different components in a device, how those components relate to one another, and how network communication takes place. The following paragraphs briefly describe object-oriented modeling and how these concepts are used within the *DeviceNet Specification*.

In object-oriented terminology, a classification of components with similar qualities is called a *class*. For example, different classes of geometric shapes could include squares, circles, and triangles. Figure A-1 shows various classes and instances of geometric shapes.

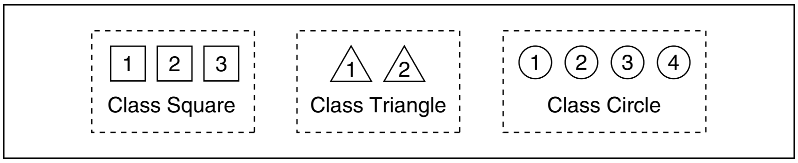


Figure A-1. Classes of Geometric Shapes

All squares belong to the same class because they all have similar qualities, such as four equal sides. The term instance refers to a specific instance of a given class. For example, a blue square of four inches per side would be one instance of the class square, and a red square of five inches per side would be another instance. The term object is often used as a synonym for the term instance, although in some contexts it might also refer to a class.

Each class defines a set of attributes which represent its externally visible characteristics. The set of attributes defined by a class is common to all instances within that class. For the class square, attributes could include length of each side and color. For the class circle, attributes could include radius and color. Each class also defines a set of services (or methods) which is used to perform an operation on an instance. For the class square, services could include resize, rotate, or change color.

Object Modeling in the DeviceNet Specification

Figure A-2 illustrates the object modeling used within the *DeviceNet Specification*.

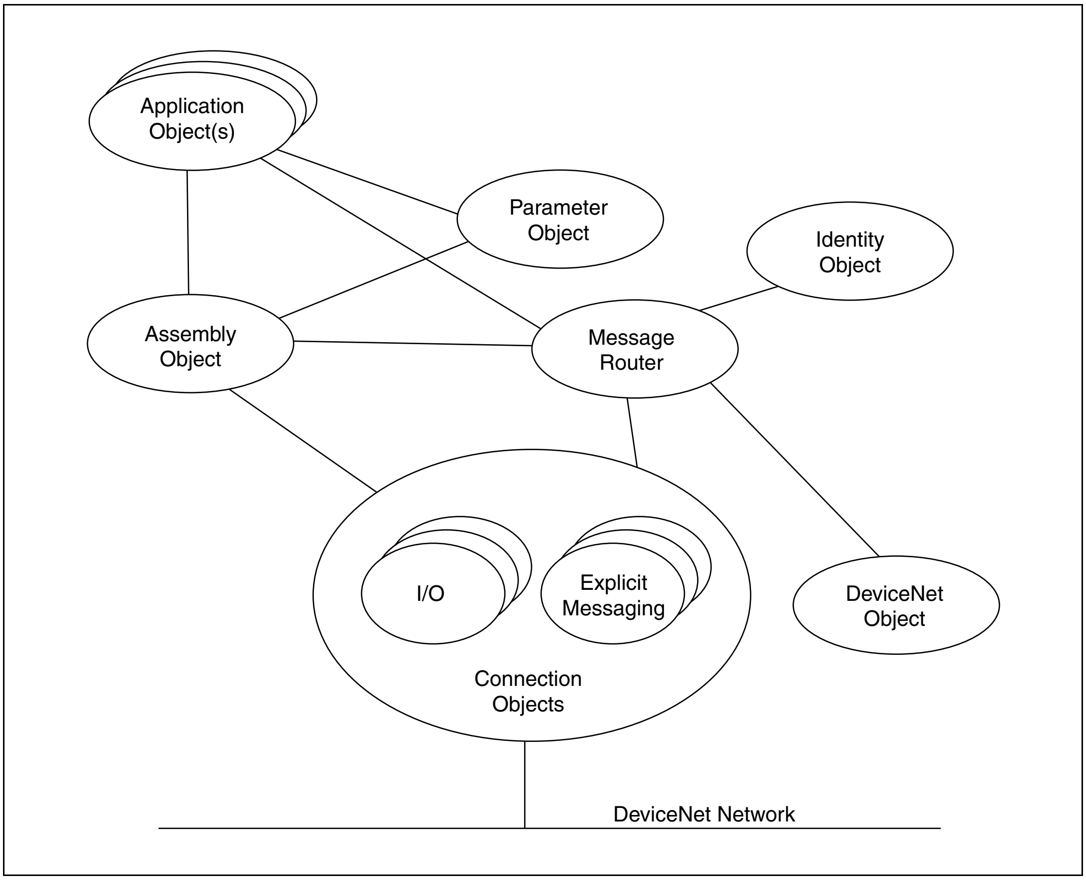


Figure A-2. Object Modeling Used in DeviceNet Specification

Every DeviceNet device contains at least one instance (instance one) of the Identity Object. The Identity Object instance defines attributes which describe the device, including the device's vendor, product name, and serial number. The Identity Object also defines services which apply to the entire device. For example, if you use the Reset service on instance one of the Identity Object, the device resets to its power on state.

Another class of object contained in every DeviceNet device is the Connection Object. Each instance of the Connection Object represents a communication path to one or more devices. Attributes of each Connection Object instance include the maximum number of bytes produced on the connection, the maximum number of bytes consumed, and the expected rate at which data is transferred.

In Figure A-2, the term Application Object(s) refers to objects within the device which are used to perform its fundamental behavior. For example, within a photoelectric sensor, an instance of the Presence Sensing object (an Application Object) represents the physical photoelectric sensor hardware. Within a position controller device, an instance of the Position Controller object (an Application Object) is provided for every axis (motor) which can be controlled using the device.

For more information on the classes, instances, attributes, and services provided by DeviceNet, refer to the *DeviceNet Specification*. You can find additional information on the specific classes and instances supported by a given device in the documentation that came with the device.

Although the NI-DNET driver software provides object instances which are used to access the DeviceNet network, these objects do not correspond directly to the objects defined by the *DeviceNet Specification*, and the NI-DNET functions do not directly correspond to the services defined by DeviceNet. To facilitate access to your DeviceNet network, the features provided by the NI-DNET driver are a simplification of the objects and services defined in the *DeviceNet Specification*.

Explicit Messaging Connections

Each device on the DeviceNet network supports at least one explicit messaging connection. Explicit messaging connections provide a general-purpose communication path used to execute services on a particular object in a device.

For a given explicit messaging connection between two DeviceNet devices, the device requesting execution of the service is called the *client*, and the device to which the service request is directed is called the *server*. Your NI-DNET software can be used as an explicit messaging client with any number of DeviceNet server devices.

Using an explicit messaging connection, the client device sends an explicit message request to the server device. This request indicates the service to perform and the object to which the service is directed. When the server receives the explicit message request, it executes the service and sends an explicit message response to the client device. If the service executed successfully, this response contains information requested by the client.

The MAC ID (address) of the explicit message client and server is contained in the header of the DeviceNet explicit messages.

The following tables describe the general format of DeviceNet explicit message requests and responses as they appear on the DeviceNet network.

Table A-2. Explicit Message Request

Field	Description
Service Code	This number identifies the service requested by the client. The *DeviceNet Specification* defines valid service codes.
Class ID	This number identifies the class to which the service is directed. The *DeviceNet Specification* defines valid class IDs.
Instance ID	This number identifies the instance to which the service is directed. If the instance ID is zero, the service is directed to the entire class. If the instance ID is one or greater, the service is directed to a specific instance within the class.
Service Data	Data bytes specific to the Service Code. The number and format of these data bytes is defined by the specification for the service.

Table A-3. Explicit Message Response

Field	Description
Service Code	This number indicates success or failure for execution of the service. If this number is the same as the Service Code of the request, the service executed successfully. If this number is 14 hex, the service failed to execute due to an error.
Service Data	If the service executed successfully, this field contains data bytes which are specific to the Service Code. The number and format of these data bytes are defined by the specification for the service. If the service failed to execute, the first byte of Service Data contains a General Error Code which describes the error, and the second byte contains an Additional Error Code which qualifies the error. The *DeviceNet Specification* defines valid values for the General Error Code and Additional Error Code.

The DeviceNet Specification defines a set of services supported in a common way by different devices. These common services include Reset, Save, Restore, Get Attribute Single, and Set Attribute Single.

The Get Attribute Single service obtains the value of a specific attribute within a device's object, and the Set Attribute Single service sets the value of an attribute. These Get and Set services are the most commonly used explicit messaging services. Since these two services are used often, NI-DNET provides functions for these services: `ncGetDnetAttribute` and `ncSetDnetAttribute`.

Other services defined by DeviceNet are used less often. For these services, NI-DNET provides general purpose functions to send an explicit message request (`ncWriteDnetExplMsg`) and receive an explicit message response (`ncReadDnetExplMsg`). These NI-DNET functions use parameters which are similar to the explicit message request/response listed above. For more information on DeviceNet common services other than Get/Set Attribute Single, refer to the *DeviceNet Specification*.

I/O Connections

In addition to explicit messaging connections, DeviceNet devices provide another type of Connection Object called an I/O connection. I/O connections provide a communication path for the exchange of physical input/output (sensor/actuator) data as well as other control-oriented data. I/O connections are useful for transferring data at regular intervals.

Since many DeviceNet devices do not begin their normal operation until an I/O connection is established, explicit messaging is often used for configuration and initialization. For example, for a device with an analog input, the I/O connection is normally used to read the analog input measurement, and explicit messages are used for configuration such as setting the measurement range and units (such as –10 to +10 V versus 4 to 20 mA).

The *DeviceNet Specification* defines two types of I/O connections: master/slave and peer-to-peer. In master/slave I/O connections, a master device uses an I/O connection to communicate with one or more slave devices, and those slave devices can only communicate with the master and not one another. In peer-to-peer I/O connections, each device on the network can communicate as a peer, and communication paths between peer devices are established as needed. The NI-DNET software currently supports only master/slave I/O connections because the procedure used to establish these I/O connections is more well defined. For this reason, almost all existing DeviceNet devices only implement master/slave I/O connections.

The *DeviceNet Specification* defines four types of master/slave I/O connections: polled, bit strobed, change-of-state (COS), and cyclic. A slave device can support at most one polled, one strobed, and one COS or cyclic connection (COS and cyclic connections cannot be used simultaneously).

Polled I/O

The polled I/O connection uses a request/response scheme for each device. The master sends a poll command (request) message to the slave device with any amount of output data. The slave then sends a poll response message back to the master with any amount of input data. The poll command/response messages are handled individually for each slave which supports polled I/O connections. Polled I/O is typically used for devices which provide both input and output data, such as position controllers and modular I/O devices.

Figure A-3 shows an example of four polled slave devices.

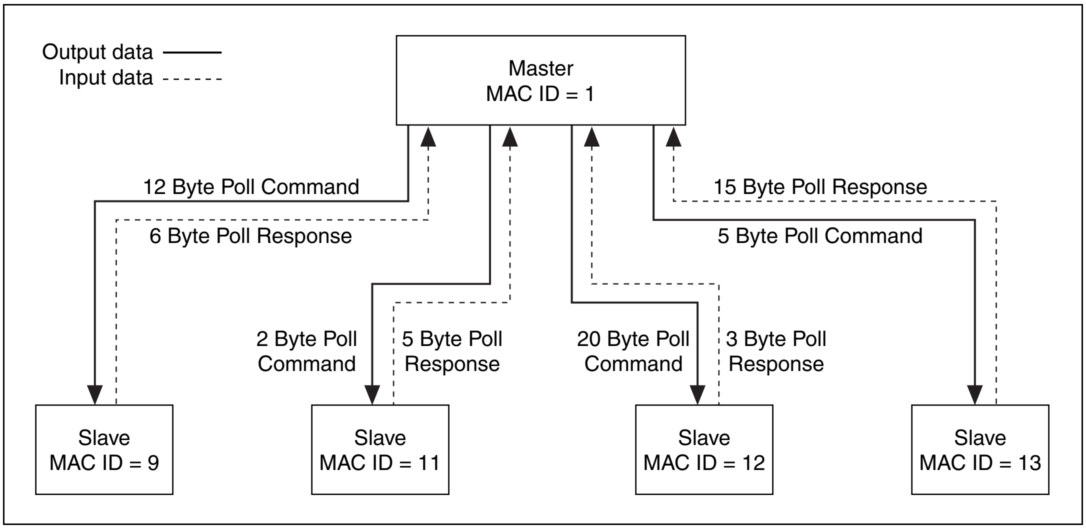


Figure A-3. Polled I/O Example

Bit Strobed I/O

The (bit) strobed I/O connection is designed to move small amounts of input data from the slave to its master. Strobed I/O is typically used for simple sensors, such as photoelectric sensors and limit switches. Strobed I/O is also called bit strobed I/O since the master sends a 64-bit (8-byte) message containing a single bit of output data for each strobed slave. This strobe command (request) message is received by all slave devices simultaneously and can be used to trigger simultaneous measurements (such as to take multiple photoelectric readings simultaneously).

When a strobed slave receives the strobe command, it uses the output data bit that corresponds to its own MAC ID (for example, the slave with MAC ID 5 uses bit 5). Regardless of the value of its output bit, each strobed slave responds to the command message by sending an individual strobe message back to the master. The slave's strobe response contains from 0 to 8 bytes of input data.

Figure A-4 shows an example of four strobed slave devices.

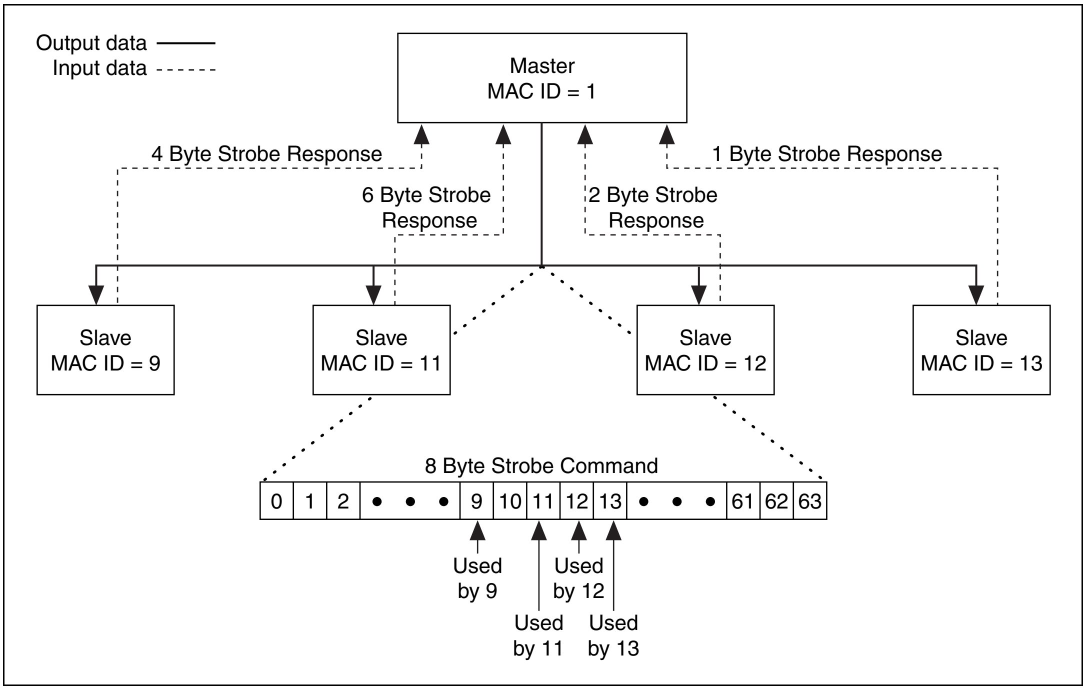


Figure A-4. Strobed I/O Example

Change-of-State and Cyclic I/O

The change-of-state (COS) and cyclic I/O connections both use the same underlying communication mechanisms. Both transmit data at a fixed interval called the expected packet rate (EPR). Since COS and cyclic I/O connections use the same messaging on the DeviceNet network, they are often referred to as a single I/O connection called COS/cyclic I/O.

The cyclic I/O connection enables a slave device to send input data to its master at the configured EPR interval. You normally configure the EPR to be consistent with the rate at which the device measures its physical input sensors. For example, if a temperature sensor can take a measurement at most once every 500 ms, you would configure the cyclic I/O connection's EPR as 500 ms. Cyclic I/O can be configured to send output data from master to slave, but this configuration is seldom used since it is essentially the same as polled I/O. Cyclic I/O messages can contain any amount of data.

The COS I/O connection enables a slave device to send input data to its master when a change is detected on its physical inputs. In addition to sending input data when a change is detected, the COS slave also sends its input data at a slower EPR interval that lets the master know it is still functioning. COS I/O is typically used for devices with physical inputs that can change frequently but can have the same input value for a long time. For example, if a pushbutton device supports COS I/O, you might configure its EPR as 3 seconds since the device sends a message immediately if a button is pressed. COS I/O can be configured to send output data from master to slave. Although master-to-slave COS output is seldom used, it can be useful for things like front-panel pushbuttons which are sent to a slave's discrete outputs (such as LEDs and simple motors). COS I/O messages can contain any amount of data.

When using COS/cyclic I/O connections, you can configure the device that receives data to send an acknowledgment so that the transmitting device can verify that the data was received successfully. For example, if you configure slave-to-master COS I/O (input length nonzero), the master sends an acknowledgment to the slave each time it receives an input message. Since the acknowledgment message is used for verification only, it does not contain data. If this verification can be handled using other means (such as using strobed I/O to verify device status), the acknowledgment message can be suppressed. For information on how to suppress COS/cyclic acknowledgments using NI-DNET, refer to the description of the I/O Object in the *NI-DNET Programmer Reference Manual*.

Since COS and cyclic I/O use the same messages on the DeviceNet network, they cannot be used simultaneously for a given slave device. Also, polled I/O uses the same messages on the DeviceNet network as master-to-slave output messages of COS/cyclic I/O. This means that a slave device can use slave-to-master COS/cyclic I/O simultaneously with polled I/O, but not master-to-slave COS/cyclic I/O.

Figure A-5 shows an example of four COS/cyclic I/O connections.

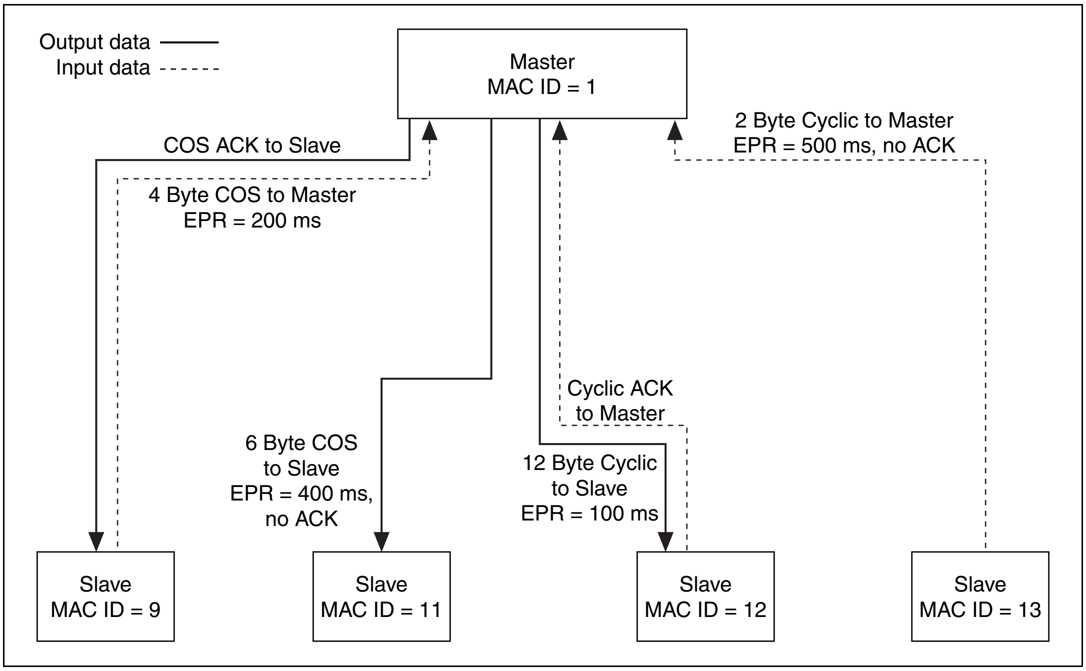


Figure A-5. COS/Cyclic I/O Example

Assembly Objects

One of the more important objects in the *DeviceNet Specification* is the Assembly Object. There are two types of Assembly Object: input assemblies and output assemblies. Assembly objects act like a switchboard, routing incoming and outgoing data to its proper location within the device. Output assemblies receive an output message from an I/O connection and distribute its contents to multiple attributes within the slave. Input assemblies gather multiple attributes within the slave for transmission on an I/O connection.

Figure A-6 shows the operation of input and output assemblies.

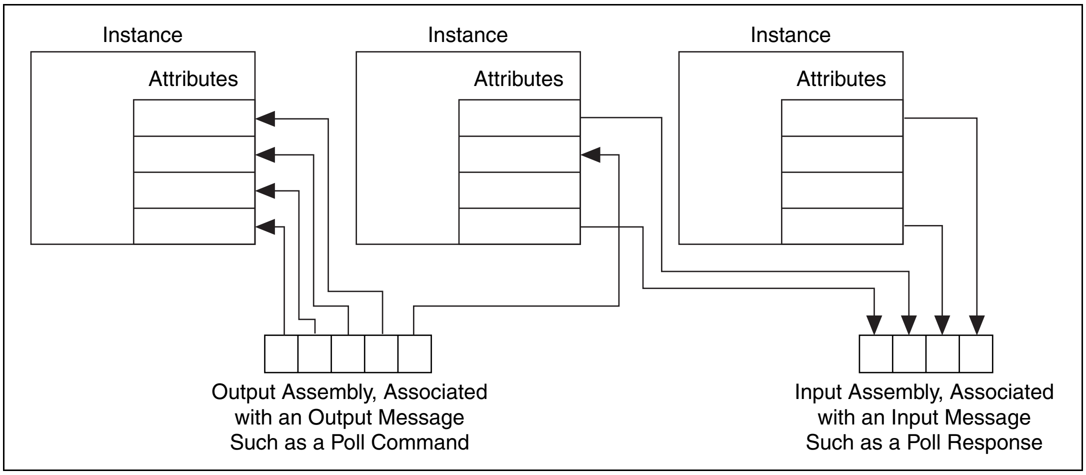

Instance
Attributes
Instance
Attributes
Instance
Attributes
Output Assembly, Associated with an Output Message Such as a Poll Command
Input Assembly, Associated with an Input Message Such as a Poll Response

Figure A-6. Input and Output Assemblies

As a more specific example, consider a DeviceNet photoelectric sensor (photoeye) or a limit switch. These devices contain a single instance of a class called the Presence Sensing object. This instance has attributes for the Output Signal (on/off) and Diagnostic Status (good/fault). These two attributes are often routed through a single input assembly consisting of a single byte.

Figure A-7 shows an example of a Presence Sensing instance and its input assembly.

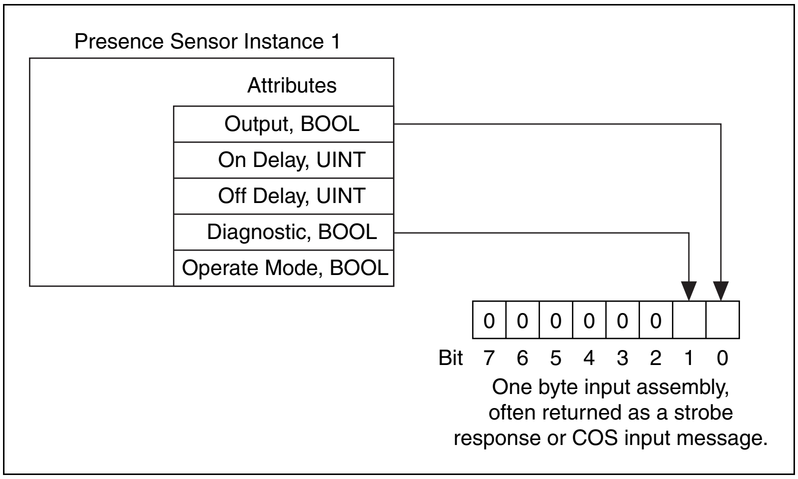


Figure A-7. Input Assembly for Photoeye or Limit Switch

As you can see, to use the data bytes contained in I/O messages, it is important to know the format of a device's internal input and output assemblies.

Device Profiles

To provide interoperability for devices of the same type, the *DeviceNet Specification* defines various device profiles. The goal behind device profiles is that for a given type of device, such as a photoelectric sensor, it should be relatively straightforward to replace a sensor from one vendor with a sensor from another vendor.

All devices which conform to a given profile must do the following:

- Exhibit the same behavior
- Use the same object model (certain instances are required)
- Contain the same input and output assemblies
- Contain the same set of configurable attributes

In addition to required features, most device profiles define a variety of optional features. When an optional feature is supported by a vendor, it must be supported as defined by the *DeviceNet Specification*. Device profiles also allow for vendor-specific features.

The *DeviceNet Specification* provides device profiles for such devices as photoelectric sensors, limit switches, motor starters, position controllers, and mass-flow controllers.

Open DeviceNet Vendors Association (ODVA)

This chapter provides only a short summary of DeviceNet. For additional information, such as a list of DeviceNet products and how to purchase the *DeviceNet Specification*, refer to the ODVA Web site at `www.odva.org`.

B

Cabling Requirements

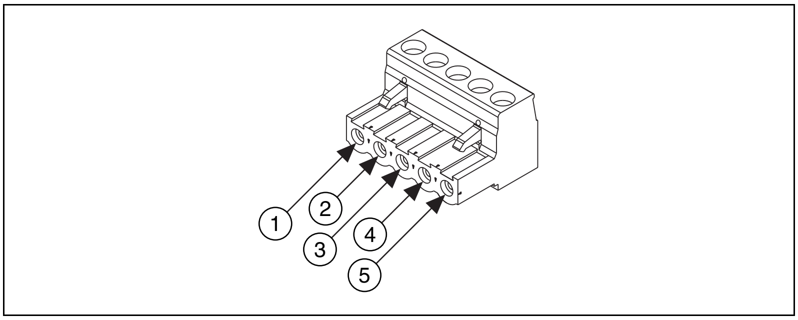
This appendix describes the cabling requirements for the hardware.

Cables should be constructed to meet these requirements as well as the requirements of DeviceNet. DeviceNet cabling requirements can be found in the *DeviceNet Specification*.

Connector Pinouts

The PCI-CAN, PXI-8461, and the PCMCIA-CAN bus-powered cable each have a Combicon-style pluggable screw terminal connector. The PCMCIA-CAN bus-powered cable also has a DB-9 D-SUB connector.

The 5-pin Combicon-style pluggable screw terminal follows the pinout required by the *DeviceNet Specification*. Figure B-1 shows the pinout for this connector.



1	V+	3	Shield	5	V–
2	CAN_H	4	CAN_L		

Figure B-1. Pinout for 5-Pin Combicon-Style Pluggable Screw Terminal

CAN_H and CAN_L are signal lines that carry the data on the DeviceNet network. These signals should be connected using twisted-pair cable.

The V+ and V– signals supply power to the DeviceNet physical layer. Refer to the *Power Supply Information for the DeviceNet Ports* section for more information.

Figure B-2 shows the end of a PCMCIA-CAN bus-powered cable. The arrow points to pin 1 of the 5-pin screw terminal block. All of the signals on the 5-pin Combicon-style pluggable screw terminal are connected directly to the corresponding pins on the 9-pin D-SUB following the pinout in Figure B-3.

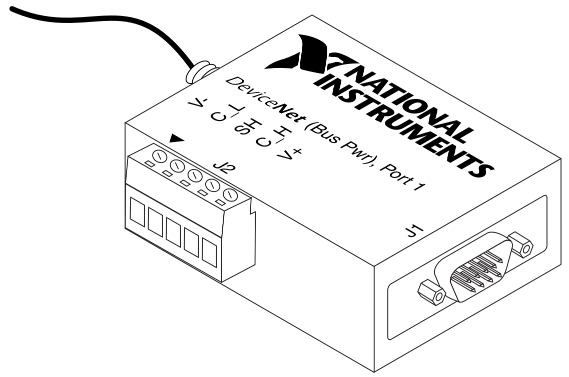


Figure B-2. PCMCIA-CAN Bus-Powered Cable

The 9-pin D-SUB follows the pinout recommended by CiA Draft Standard 102. Figure B-3 shows the pinout for this connector.

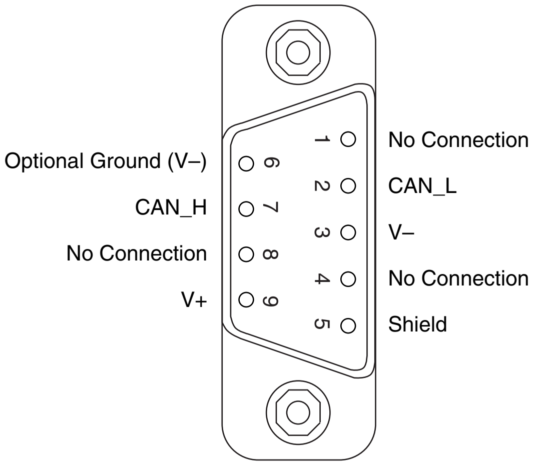


Figure B-3. Pinout for 9-Pin D-SUB Connector

Power Supply Information for the DeviceNet Ports

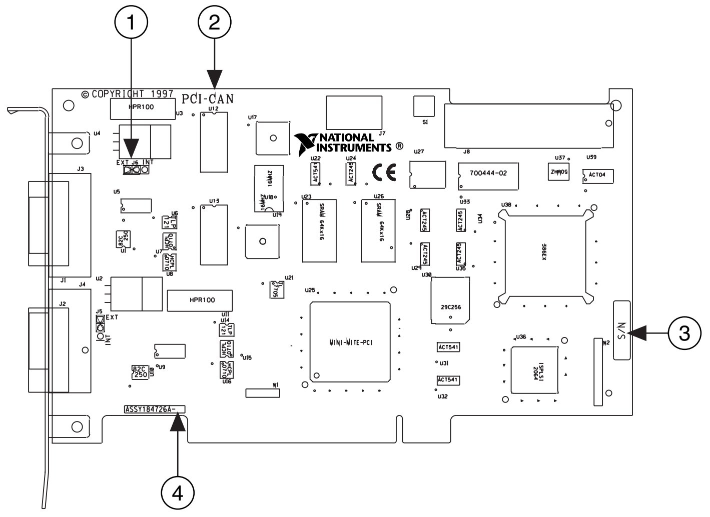
The bus must supply power to each DeviceNet port. The bus power supply should be a DC power supply with an output of 10 V to 30 V. The DeviceNet physical layer is powered from the bus using the V+ and V– lines.

The power requirements for the DeviceNet port are shown in Table B-1. You should take these requirements into account when determining the requirements of the bus power supply for the system.

Table B-1. Power Requirements for the DeviceNet Physical Layer for Bus-Powered Versions

Characteristic	Specification
Voltage Requirement	V+ 10 to 30 VDC
Current Requirement	40 mA typical 100 mA maximum

For the PCI-CAN, a jumper controls the source of power for the DeviceNet physical layer. The location of this jumper is shown in Figure B-4.



1 Power Supply Jumper J6	3 Serial Number
2 Product Name	4 Assembly Number

Figure B-4. PCI-CAN Power Source Jumper

The PCI-CAN is shipped with this jumper set in the EXT position. In this position, the physical layer is powered from the bus (the V+ and V– pins on the Combicon connector). The jumper must be in this position for the DeviceNet interface to be compliant with the *DeviceNet Specification*.

If the DeviceNet interface is being used in a system where bus power is not available, the jumper may be set in the INT position. In this position, the physical layer is powered by the host computer or internally. The physical layer is still optically isolated. Figure B-5 shows how to configure your jumpers for internal or external power supplies.

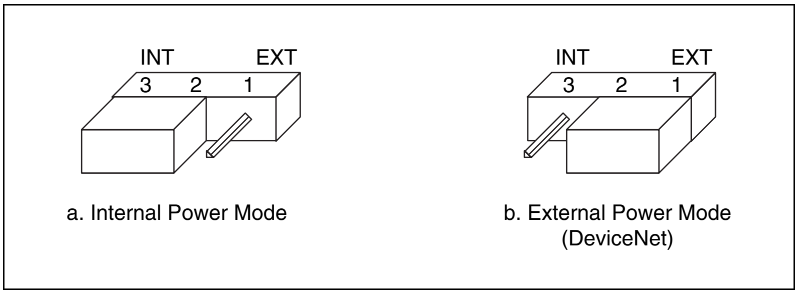
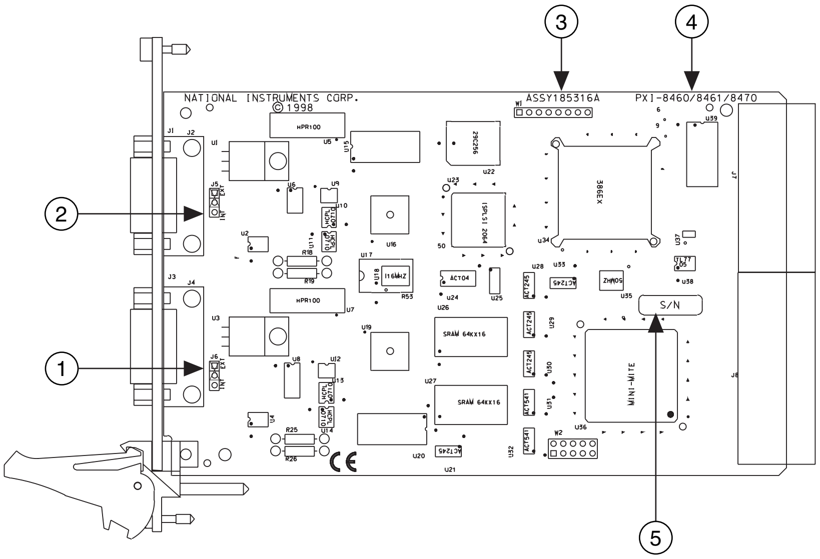


Figure B-5. Power Source Jumpers

For port one of the PXI-8461, power is configured with jumper J5. The location of these jumper is shown in Figure B-6.



1	Power Supply Jumper J6	3	Assembly Number	5	Serial Number
2	Power Supply Jumper J5	4	Product Name		

Figure B-6. PXI-8461 Parts Locator Diagram

Connecting pins 1 and 2 of a jumper configures the PXI-8461 physical layer to be powered externally (from the bus cable power). In this configuration, the power must be supplied on the V+ and V– pins on the port connector. The jumper must be in this position for the DeviceNet interface to be compliant with the *DeviceNet Specification*.

Connecting pins 2 and 3 of a jumper configures the PXI-8461 physical layer to be powered internally (from the board). In this configuration, the V– signal serves as the reference ground for the isolated signals.

The PCMCIA-CAN is shipped with the bus power version of the PCMCIA-CAN cable. An internally-powered version of the PCMCIA-CAN cable can be ordered from National Instruments.

Cable Specifications

Cables should meet the requirements of the DeviceNet cable specification. DeviceNet cabling requirements can be found in the *DeviceNet Specification*.

Belden cable (3084A) meets all of those requirements and should be suitable for most applications.

Cable Lengths

The allowable cable length is affected by the characteristics of the cabling and the desired bit transmission rates. Detailed cable length requirements can be found in the *DeviceNet Specification*.

Table B-2 lists the DeviceNet cable length specifications.

Table B-2. DeviceNet Cable Length Specifications

Baud Rate	Trunk Length	Drop Length Maximum	Drop Length Cumulative
500 kb/s	100 m (328 ft)	6 m (20 ft)	39 m (128 ft)
250 kb/s	250 m (820 ft)	6 m (20 ft)	78 m (256 ft)
125 kb/s	500 m (1640 ft)	6 m (20 ft)	156 m (512 ft)

Maximum Number of Devices

The maximum number of devices that you can connect to a DeviceNet port depends on the electrical characteristics of the devices on the network. If all of the devices on the network meet the DeviceNet specifications, 64 devices may be connected to the network.

Cable Termination

The pair of signal wires (CAN_H and CAN_L) constitutes a transmission line. If the transmission line is not terminated, each signal change on the line causes reflections that may cause communication failures.

Because communication flows both ways on the DeviceNet bus, DeviceNet requires that both ends of the cable be terminated. However, this requirement does not mean that every device should have a termination resistor. If multiple devices are placed along the cable, only the devices on the ends of the cable should have termination resistors. Refer to Figure B-7 for an example of where termination resistors should be placed in a system with more than two devices.

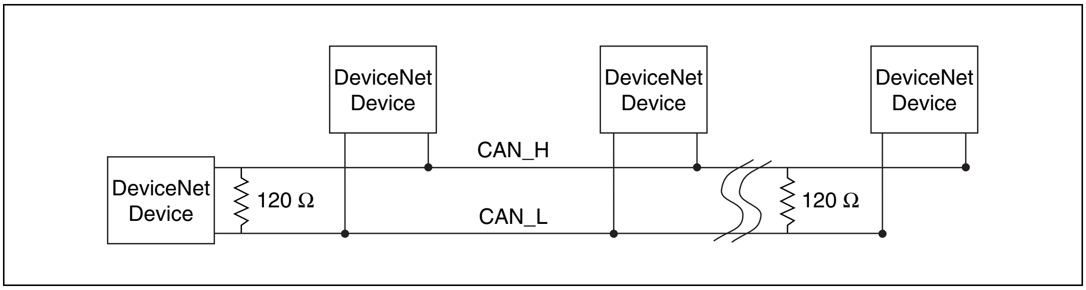


Figure B-7. Termination Resistor Placement

The termination resistors on a cable should match the nominal impedance of the cable. DeviceNet requires a cable with a nominal impedance of 120 Ω; therefore, a 120 Ω resistor should be used at each end of the cable. Each termination resistor should each be capable of dissipating at least 0.25 W of power.

Cabling Example

Figure B-8 shows an example of a cable to connect two DeviceNet devices.

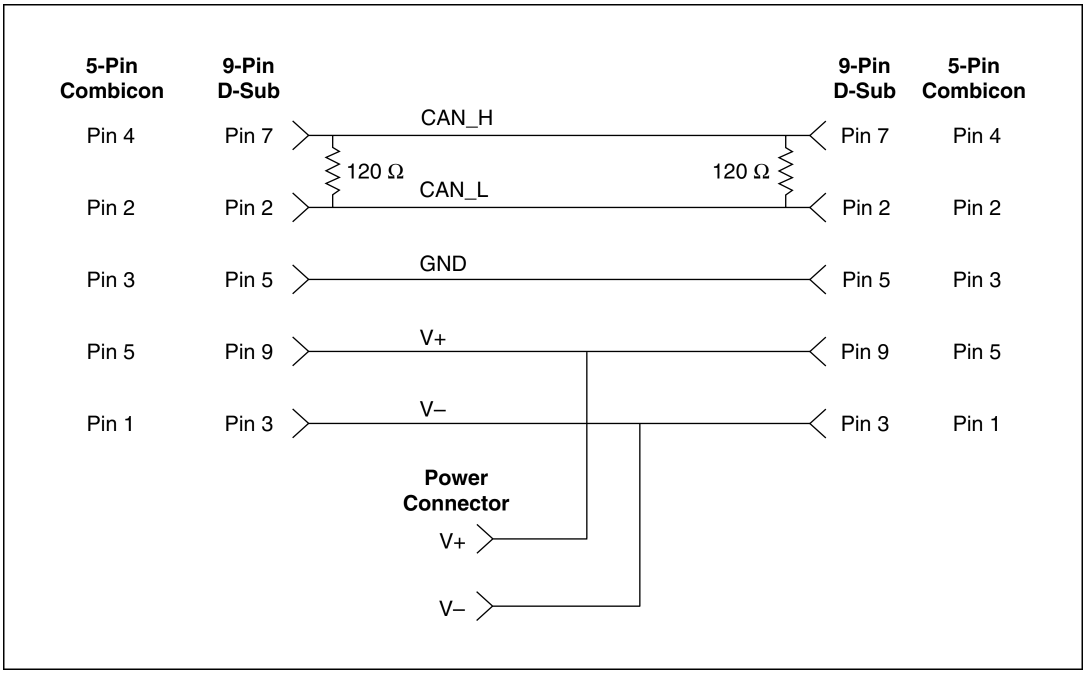


Figure B-8. Cabling Example

C

Troubleshooting and Common Questions

This appendix describes how to troubleshoot problems with the NI-DNET software and answers some common questions.

Troubleshooting with the Measurement & Automation Explorer (MAX)

MAX contains configuration information for all CAN (DeviceNet) hardware installed on your system. To start MAX, double-click on the **Measurement & Automation** icon on your desktop. Your CAN cards are listed in the left pane (Configuration) under **Devices and Interfaces.**

You can test your CAN cards by choosing **Tools»NI-CAN»Test all Local NI-CAN Cards** from the menu, or you can right-click on an CAN card and choose **Self Test**. If the Self Test fails, refer to the *Troubleshooting Self Test Failures* section of this appendix.

Missing CAN Card

If you have a CAN card installed, but no CAN card appears in the configuration section of MAX under **Devices and Interfaces,** you need to search for hardware changes by pressing <F5> or choosing the **Refresh** option from the **View** menu in MAX.

If the CAN card still doesn't show up, you may have a resource conflict in the Windows Device Manager. Refer to the documentation for your Windows operating system for instructions on how to resolve the problem using the Device Manager.

Troubleshooting Self Test Failures

The following topics explain common error messages generated by the Self Test in MAX.

Application In Use

This error occurs if you are running an application that is using the CAN card. The self test aborts to avoid adversely affecting your application. Before running the self test, exit all applications that use NI-DNET or NI-CAN. If you are using LabVIEW, you may need to exit LabVIEW to unload the NI-DNET driver.

Memory Resource Conflict

This error occurs if the memory resource assigned to a CAN card conflicts with the memory resources being used by other devices in the system. Resource conflicts typically occur when your system contains legacy boards that use resources not properly reserved with the Device Manager. If a resource conflict exists, write down the memory resource that caused the conflict and refer to the documentation for your Windows operating system for instructions on how to use the Device Manager to reserve memory resources for legacy boards. After the conflict has been resolved, run the Self Test again.

Interrupt Resource Conflict

This error occurs if the interrupt resource assigned to a CAN card conflicts with the interrupt resources being used by other devices in the system. Resource conflicts typically occur when your system contains legacy boards that use resources not properly reserved with the Device Manager. If a resource conflict exists, write down the interrupt resource that caused the conflict and refer to the documentation for your Windows operating system for instructions on how to use the Device Manager to reserve interrupt resources for legacy boards. After the conflict has been resolved, run the Self Test again.

NI-CAN Software Problem Encountered

This error occurs if the Self Test detects that it is unable to communicate correctly with the CAN hardware using the installed NI-CAN or NI-DNET software. If you get this error, shut down your computer, restart it, and run the Self Test again.

If the error continues after restart, uninstall NI-CAN (and NI-DNET) and then reinstall.

NI-CAN Hardware Problem Encountered

This error occurs if the Self Test detects a defect in the CAN hardware. If you get this error, write down the numeric code shown with the error and contact National Instruments.

Common Questions

How can I determine which version of the NI-DNET software is installed on my system?

Within MAX, open the **Software** branch and select **NI-DNET**. The version is displayed in the right pane of MAX.

How many CAN cards can I configure for use with my NI-DNET software?

The NI-DNET software can be configured to communicate with up to 32 CAN cards on all supported operating systems.

Which CAN hardware for DeviceNet does the NI-DNET software support?

The NI-DNET software for supports Port 1, Series 1, High-Speed (HS) cards. Although you can use 2-port CAN cards, only the top port can be used with NI-DNET. For more information, refer to Chapter 2, *NI-DNET Hardware Overview*.

Does NI-DNET support 2-port CAN cards?

Refer to the previous question.

Are interrupts required for the NI-CAN cards?

Yes, one interrupt per card is required. However, PCI and PXI CAN cards can share interrupts with other devices in the system.

Does the CAN card provide power to the CAN bus?

No. To provide power to the CAN bus, you need an external power supply.

Can I use multiple PCMCIA cards in one computer?

Yes, but make sure there are enough free resources available. Unlike PCI or PXI CAN cards, PCMCIA CAN cards cannot share resources, such as IRQs, with other devices.

I have problems with my NI PCMCIA CAN card under Windows NT. How can I resolve them?

Windows NT offers minimal support for plug and play and there are several things to consider.

Because Windows NT does not automatically assign resources to PCMCIA cards, the PCMCIA CAN cards are configured to use default values for the IRQ and the memory range. If those resources are already in use by other devices, it might be necessary to manually change those values.

To do so, right-click the PCMCIA CAN card in MAX and choose **Properties**. Assign resource values that do not conflict with other device resources for either the Interrupt Request (IRQ) or the Memory Range.

Initially, all NI PCMCIA CAN cards will have the same resources assigned. If you have more than one PCMCIA CAN card installed, the Self Test will fail. You must change the resources of one of the cards manually.

Windows NT does not allow more than one PCMCIA card of the same type installed. Thus, you cannot use two NI PCMCIA cards in the same system.

Why are some components left after the NI-DNET software is uninstalled?

The uninstall program removes only items that the installation program installed. If you add anything to a directory that was created by the installation program, the uninstall program does not delete that directory, because the directory is not empty after the uninstallation. You must remove any remaining components yourself.

D

Hardware Specifications

This appendix describes the physical characteristics of the DeviceNet hardware, along with the recommended operating conditions.

PCI-CAN Series

Dimensions	10.67 by 17.46 cm (4.2 by 6.9 in.)
Power requirement	+5 VDC, 775 mA typical
I/O connector	5-pin Combicon-style pluggable DeviceNet screw terminal (high-speed CAN only)
Operating environment	
Ambient temperature	0 to 55 °C
Relative humidity	10 to 90%, noncondensing
Storage environment	
Ambient temperature	–20 to 70 °C
Relative humidity	5 to 90%, noncondensing

PCMCIA-CAN Series

Dimensions	8.56 by 5.40 by 0.5 cm (3.4 by 2.1 by 0.4 in.)
Power requirement	500 mA typical
I/O connector	Cable with 9-pin D-SUB and pluggable screw terminal for each port
Operating environment	
Ambient temperature	0 to 55 °C
Relative humidity	10 to 90%, noncondensing

Storage environment

Ambient temperature	–20 to 70 °C
Relative humidity	5 to 90%, noncondensing

PXI-CAN Series

Dimensions	16.0 by 10.0 cm (6.3 by 3.9 in.)
Power requirement	+5 VDC, 775 mA typical
I/O connector	9-pin D-SUB for each port (standard) or 5-pin Combicon-style pluggable DeviceNet screw terminal (high-speed CAN only)

Operating environment

Ambient temperature	0 to 55 °C
Relative humidity	10 to 90%, noncondensing

Storage environment

Ambient temperature	–20 to 70 °C
Relative humidity	5 to 95%, noncondensing

(Tested in accordance with IEC-60068-2-1, IEC-60068-2-2, IEC-60068-2-56.)

Functional Shock	30 g peak, half-sine, 11ms pulse

(Tested in accordance with IEC-60068-2-27. Test profile developed in accordance with MIL-T-28800E.)

Random Vibration

Operating	5 to 500 Hz, 0.3 grms
Nonoperating	5 to 500 Hz, 2.4 grms

(Tested in accordance with IEC-60068-2-64. Nonoperating test profile developed in accordance with MIL-T-28800E and MIL-STD-810E Method 514.)

Port Characteristics

Bus power	0 to 30 V, 40 mA typical, 100 mA maximum
CAN-H, CAN-L	–8 to +18 V, DC or peak, CATI

Safety

The NI-CAN hardware meets the requirements of the following standards for safety and electrical equipment for measurement, control, and laboratory use:

- EN 61010-1, IEC 61010-1
- UL 3111-1, UL 61010B-1
- CAN/CSA C22.2 No. 1010.1

Note For UL and other safety certifications, refer to the product label, or visit `ni.com/hardref.nsf`, search by model number or product line, and click the appropriate link in the Certification column.

Pollution Degree	2
Maximum altitude	2,000 m

Indoor use only.

Electromagnetic Compatibility

Electrical emissions	EN 55011 Class A at 10 m FCC Part 15A above 1 GHz
Electrical immunity	Evaluated to EN 61326:1997 +A2:2001, Table 1

CE, C-Tick, and FCC Part 15 (Class A) Compliant

Note For EMC compliance, operate this device with shielded cabling.

CE Compliance

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

Low-Voltage Directive (safety)	73/23/EEC
Electromagnetic Compatibility Directive (EMC)	89/336/EEC

Note 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/hardref.nsf`, search by model number or product line, and click the appropriate link in the Certification column.

E

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 immediate 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.
- **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, NI Alliance Program members can help. To learn more, call your local NI office or visit `ni.com/alliance`.

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
m	milli	10^{-3}
k	kilo	10^{3}

A

A	amperes
AC	alternating current
actuator	A device that uses electrical, mechanical, or other signals to change the value of an external, real-world variable. In the context of device networks, actuators are devices that receive their primary data value from over the network; examples include valves and motor starters. Also known as *final control element.*
ANSI	American National Standards Institute
Application Programming Interface (API)	A collection of functions used by a user application to access hardware. Within NI-DNET, you use API functions to make calls into the NI-DNET driver.
ASCII	American Standard Code for Information Exchange
Assembly Object	Objects in DeviceNet devices which route I/O message contents to/from individual attributes in the device.
attribute	The externally visible qualities of an object; for example, an instance square of class Geometric Shapes could have the attributes length of sides and color, with the values 4 in. and blue.
automatic polling	A polled I/O mode in which NI-DNET automatically determines an appropriate *scanned polling* rate for your DeviceNet system.

B

b	Bits
background polling	A polled I/O communication scheme in which all polled slaves are grouped into two different communication rates: a foreground rate and a slower background rate.
bit strobed I/O	Master/slave I/O connection in which the master broadcasts a single strobe command to all strobed slaves then receives a strobe response from each strobed slave.

C

CAN	Controller Area Network
change-of-state I/O	Master/slave I/O connection which is similar to cyclic I/O but data can be sent when a change in the data is detected.
class	A classification of things with similar qualities.
client	In explicit messaging connections, the client is the device requesting execution of the service.
common services	Services defined by the DeviceNet specification such that they are largely interoperable.
connection	An association between two or more devices on a network that describes when and how data is transferred.
controller	A device that receives data from sensors and sends data to actuators to hold one or more external, real-world variables at a certain level or condition. A thermostat is a simple example of a controller.
COS I/O	*See* change-of-state I/O.
cyclic I/O	Master/slave I/O connection in which the slave (or master) sends data at a fixed interval.

D

DC	direct current
device	A physical assembly, linked to a communication line (cable), capable of communicating across the network according to a protocol specification.
device network	Multi-drop digital communication network for sensors, actuators, and controllers.
device profiles	DeviceNet specifications which provide interoperability for devices of the same type.
direct entry	Microsoft Win 32 functions used to directly access the functions of a Dynamic Link Library (DLL).
DLL	Dynamic Link Library
driver attributes	Attributes of the NI-DNET driver software.

E

EDS	Electronic Data Sheet. Text file that describes DeviceNet device features electronically.
expected packet rate	The rate (in milliseconds) at which a DeviceNet connection is expected to transfer its data.
Explicit messaging connection	General-purpose connection used for executing services on a particular object in a DeviceNet device.

F

FCC	Federal Communications Commission
ft	feet
FTP	File transfer protocol

H

hex	Hexadecimal
Hz	Hertz

I

I/O connection	Connection used for exchange of physical input/output (sensor/activator) data, as well as other control-oriented data.
in.	inches
individual polling	A polled I/O communication scheme in which each polled slave communicates at its own individual rate.
instance	A specific instance of a given class. For example, a blue square of 4 inches per side would be one instance of the class Squares.
ISO	International Standards Organization

K

KB	Kilobytes of memory

L

LabVIEW	Laboratory Virtual Instrument Engineering Workbench
LED	light-emitting diode
local	Within NI-DNET, anything that exists on the same host (personal computer) as the NI-DNET driver.

M

m	meter
MAC ID	Media access control layer identifier. In DeviceNet, a device's MAC ID represents its address on the DeviceNet network.

master/slave	DeviceNet communication scheme in which a master device allocates connections to one or more slave devices, and those slave devices can only communicate with the master and not one another.
MB	Megabytes of memory
member	Individual data value within a DeviceNet I/O Assembly.
method	*See* service.
multi-drop	A physical connection in which multiple devices communicate with one another along a single cable.

N

network interface	A device's physical connection onto a network.
network management utility	Utility used to manage configuration of DeviceNet devices.
network who	A search of a DeviceNet network to determine information about its devices.
NI-DNET driver	Device driver and/or firmware that implement all the specifics of a National Instruments DeviceNet interface.
notification	Within NI-DNET, an operating system mechanism that the NI-DNET driver uses to communicate events to your application. You can think of a notification of as an API function, but in the opposite direction.

O

object	*See* instance.
object-oriented	A software design methodology in which classes, instances, attributes, and methods are used to hide all of the details of a software entity that do not contribute to its essential characteristics.
ODVA	Open DeviceNet Vendor's Association

P

PC	personal computer
peer-to-peer	DeviceNet communication scheme in which each device communicates as a peer and connections are established among devices as needed.
PLC	Programmable Logic Controller
polled I/O	Master/slave I/O connection in which the master sends a poll command to a slave, then receives a poll response from that slave.
protocol	A formal set of conventions or rules for the exchange of information among devices of a given network.

R

RAM	Random-access memory
remote	Within NI-DNET, anything that exists in another device of the device network (not on the same host as the NI-DNET driver).
resource	Hardware settings used by National Instruments DeviceNet hardware, including an interrupt request level (IRQ) and an 8 KB physical memory range (such as `D0000` to `D1FFF` hex).

S

s	seconds
scanned polling	A polled I/O communication scheme in which all poll commands are sent out at the same rate, in quick succession.
sensor	A device that measures electrical, mechanical, or other signals from an external, real-world variable; in the context of device networks, sensors are devices that send their primary data value onto the network; examples include temperature sensors and presence sensors. Also known as transmitter.
server	In explicit messaging connections, the server is the device to which the service is directed.

service	An action performed on an instance to affect its behavior; the externally visible code of an object. Within NI-DNET, you use NI-DNET functions to execute services for objects. Also known as method and operation.
strobed I/O	*See* bit strobed I/O.

V

V	volts
VI	Virtual Instrument
VxD	Virtual device driver

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