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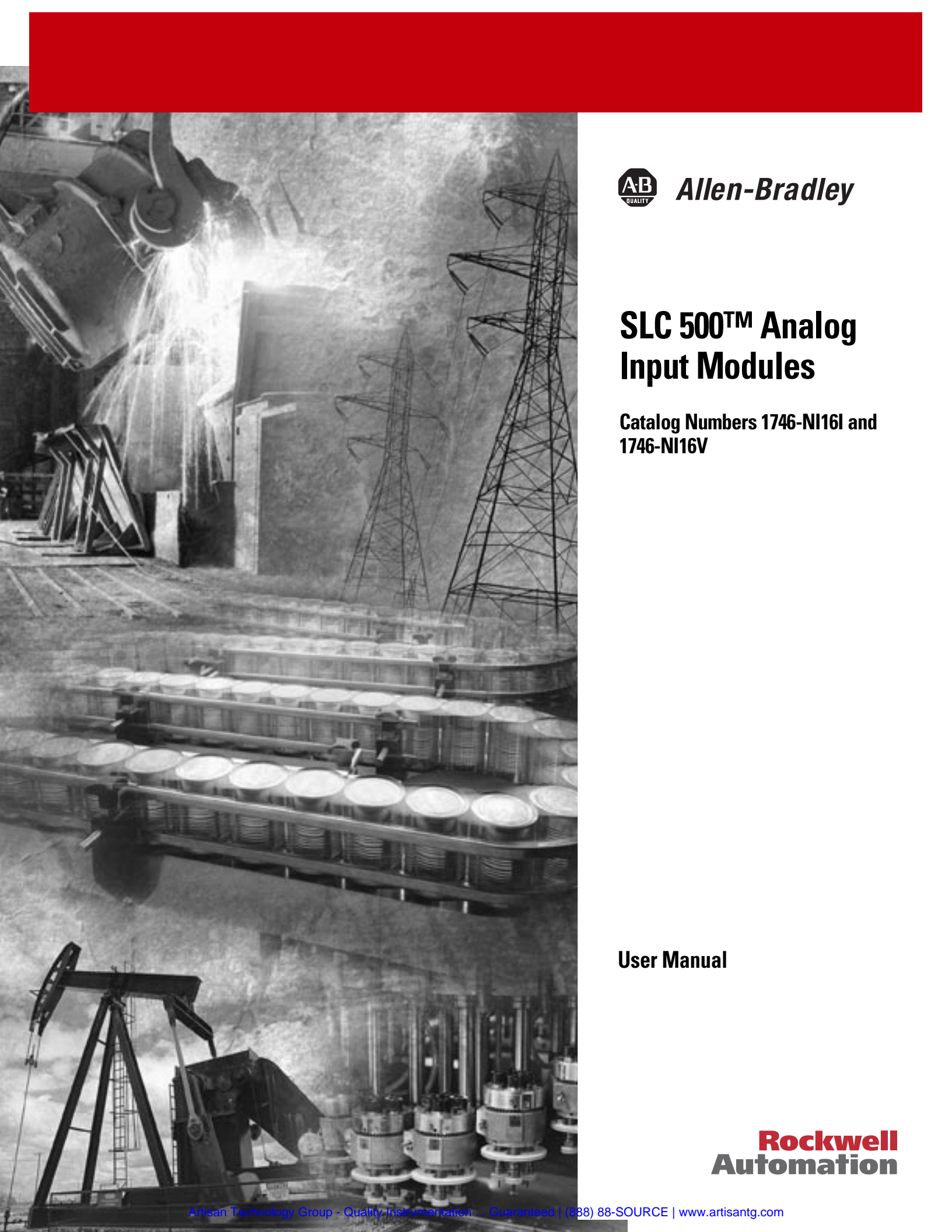
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Allen-Bradley

SLC 500™ Analog Input Modules

**Catalog Numbers 1746-NI16I and
1746-NI16V**

User Manual

**Rockwell
Automation**

Important User Information

Because of the variety of uses for the products described in this publication, those responsible for the application and use of this control equipment must satisfy themselves that all necessary steps have been taken to assure that each application and use meets all performance and safety requirements, including any applicable laws, regulations, codes and standards.

The illustrations, charts, sample programs and layout examples shown in this guide are intended solely for purposes of example. Since there are many variables and requirements associated with any particular installation, Allen-Bradley does not assume responsibility or liability (to include intellectual property liability) for actual use based upon the examples shown in this publication.

Allen-Bradley publication SGI-1.1, *Safety Guidelines for the Application, Installation and Maintenance of Solid-State Control* (available from your local Allen-Bradley office), describes some important differences between solid-state equipment and electromechanical devices that should be taken into consideration when applying products such as those described in this publication.

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Throughout this manual we use notes to make you aware of safety considerations:

ATTENTION



Identifies information about practices or circumstances that can lead to personal injury or death, property damage or economic loss

Attention statements help you to:

- identify a hazard
- avoid a hazard
- recognize the consequences

IMPORTANT

Identifies information that is critical for successful application and understanding of the product.

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Read this preface to familiarize yourself with the rest of the manual. This preface covers the following topics:

- who should use this manual
- the purpose of this manual
- contents of this manual
- related documentation
- common techniques used in this manual
- Allen-Bradley support

Who Should Use this Manual

Use this manual if you are responsible for the design, installation, programming, or maintenance of an automation control system that uses Allen-Bradley small logic controllers.

You should have a basic understanding of SLC 500™ products. You should understand electronic process control and be able to interpret the ladder logic instructions required to generate the electronic signals that control your application.

If you do not, contact your local Allen-Bradley representative for the proper training before using this product.

Purpose of this Manual

This manual is a learning and reference guide for the 1746-NI16 Analog Input Module. It contains the information you need to install, wire, and configure the module. It also provides diagnostic and troubleshooting information and application examples.

Contents of this Manual

| Chapter | Title | Content |
|------------|--|--|
| | Preface | Describes the purpose, background, and scope of this manual. Also specifies the audience for whom this manual is intended and gives directions to using Allen-Bradley support services. Provides listing of related documentation. |
| 1 | Overview | Provides a hardware and system overview. Explains and illustrates the theory behind the input module. |
| 2 | Quick Start for Experienced Users | Serves as a Quick Start Guide for the experienced user. |
| 3 | Installation and Wiring | Provides installation information and wiring guidelines. |
| 4 | Preliminary Operating Considerations | Gives you the background information you need to understand how to address and configure the module for optimum operation as well as how to make changes once the module is in a run state. |
| 5 | Channel Configuration Data and Status | Examines the channel configuration word and the channel status word, bit by bit, and explains how the module uses configuration data and generates status during operation. |
| 6 | Module Diagnostics and Troubleshooting | Explains how to interpret and correct problems that may occur while using the module. |
| 7 | Application Examples | Examines both basic and supplementary applications and gives examples of the ladder logic necessary to achieve the desired result. |
| Appendix A | Specifications | Provides physical, electrical, environmental, and functional specifications for the module. |
| Appendix B | Configuration Worksheet | Provides a worksheet to help configure the module for operation. |
| Appendix C | Two's Complement Binary Numbers | Describes the two's complement binary number system. |
| Appendix D | Calibration | Describes how to calibrate the 1746-NI16 module. |
| | Glossary | Lists key terms and abbreviations. |

Related Documentation

The following documents contain information that may be helpful to you as you use Allen-Bradley SLC products. If you would like a manual, you can:

- download a free electronic version from the internet:
www.theautomationbookstore.com
- purchase a printed manual by:
 - contacting your local distributor or Rockwell Automation representative
 - visiting **www.theautomationbookstore.com** and placing your order
 - calling **1.800.963.9548** (USA/Canada)
or **001.330.725.1574** (Outside USA/Canada)

| For | Read This Document | Document Number |
|---|---|--|
| An overview of the SLC 500 family of products | SLC 500™ System Overview | 1747-2.30 |
| A description on how to install and use your Modular SLC 500 programmable controller | Installation & Operation Manual for Modular Hardware Style Programmable Controllers | 1747-6.2 |
| A description on how to install and use your Fixed SLC 500 programmable controller | Installation & Operation Manual for Fixed Hardware Style Programmable Controllers | 1747-6.21 |
| A procedural and reference manual for technical personnel who use an HHT to develop control applications | Allen-Bradley Hand-Held Terminal User Manual | 1747-NP002 |
| An introduction to HHT for first-time users, containing basic concepts but focusing on simple tasks and exercises, and allowing the reader to quickly begin programming | Getting Started Guide for HHT | 1747-NM009 |
| A reference manual that contains status file data and instruction set information for the SLC 500 processors and MicroLogix 1000 controllers. | SLC 500™/ MicroLogix 1000™ Instruction Set Reference Manual | 1747-6.15 |
| In-depth information on grounding and wiring Allen-Bradley programmable controllers | Allen-Bradley Programmable Controller Grounding and Wiring Guidelines | 1770-4.1 |
| A description on how to install a PLC-5R system | PLC-5™ Family Programmable Controllers Hardware Installation Manual | 1785-6.6.1 |
| A description of important differences between solid-state programmable controller products and hard-wired electromechanical devices | Application Considerations for Solid-State Controls | SGI-1.1 |
| An article on wire sizes and types for grounding electrical equipment | National Electrical Code | Published by the National Fire Protection Association of Boston, MA. |
| A complete listing of current Allen-Bradley documentation, including ordering instructions. Also indicates whether the documents are available on CD-ROM or in multi-languages. | Allen-Bradley Publication Index | SD499 |
| A glossary of industrial automation terms and abbreviations | Allen-Bradley Industrial Automation Glossary | AG-7.1 |

Common Techniques Used in this Manual

The following conventions are used throughout this manual:

- Bulleted lists such as this one provide information, not procedural steps.
- Numbered lists provide sequential steps or hierarchical information.
- Text in **this font** indicates words or phrases you should type.
- Key names appear in bold, capital letters within brackets (for example, [**ENTER**]).

Allen-Bradley Support

Allen-Bradley offers support services worldwide, with over 75 Sales/Support Offices, 512 authorized Distributors and 260 authorized Systems Integrators located throughout the United States alone, plus Allen-Bradley representatives in every major country in the world.

Local Product Support

Contact your local Allen-Bradley representative for:

- sales and order support
- product technical training
- warranty support
- support service agreements

Technical Product Assistance

If you need to contact Allen-Bradley for technical assistance, please review the information in the *Troubleshooting* chapter first. Then call your local Allen-Bradley representative.

Your Questions or Comments on this Manual

If you find a problem with this manual, please notify us of it on the enclosed Publication Problem Report.

If you have any suggestions for how this manual could be made more useful to you, please contact us at the address below:

Allen-Bradley
Control and Information Group
Technical Communication, Dept. A602V, T122
P.O. Box 2086
Milwaukee, WI 53201-2086

Overview

This chapter describes the 1746-NI16 analog input module and explains how the SLC 500 processor gathers analog input data from the module. Included is information about:

- the module's hardware and diagnostic features
- an overview of system operation

General Description

The module receives and stores digitally converted analog data into its image table for retrieval by all fixed and modular SLC 500 processors. The modules, 1746-NI16V and 1746-NI16I, support connections for up to 16 voltage or current analog sensors.

The 1746-NI16 is a multi-class (Class 1 or Class 3) single-slot module. Class 1⁽¹⁾ configuration utilizes 8 input words and 8 output words. Class 3 configuration utilizes 32 input words and 32 output words. Fixed and SLC 5/01 processors can only operate as Class 1. When the module is used in a remote I/O chassis with a 1747-ASB, it can only operate in Class 1 mode. The SLC 5/02, SLC 5/03, SLC 5/04 and SLC 5/05 processors can be configured for either Class 1 or Class 3. When the module is used in a remote ControlNet™ chassis with a 1747-ACN(R), it can also operate in either Class 1 or Class 3 mode. Operate the module in Class 3 mode whenever possible.

The 16 high-impedance input channels can be wired as single-ended inputs. The module provides a direct interface to the following input types:

- $\pm 10\text{V}$ dc
- 1 to 5V dc
- 0 to 5V dc
- 0 to 10V dc
- 0 to 20 mA
- 4 to 20 mA
- ± 20 mA
- 0 to 1 mA

⁽¹⁾ Requires use of block transfer in a remote configuration.

The data presented to the processor can be configured as:

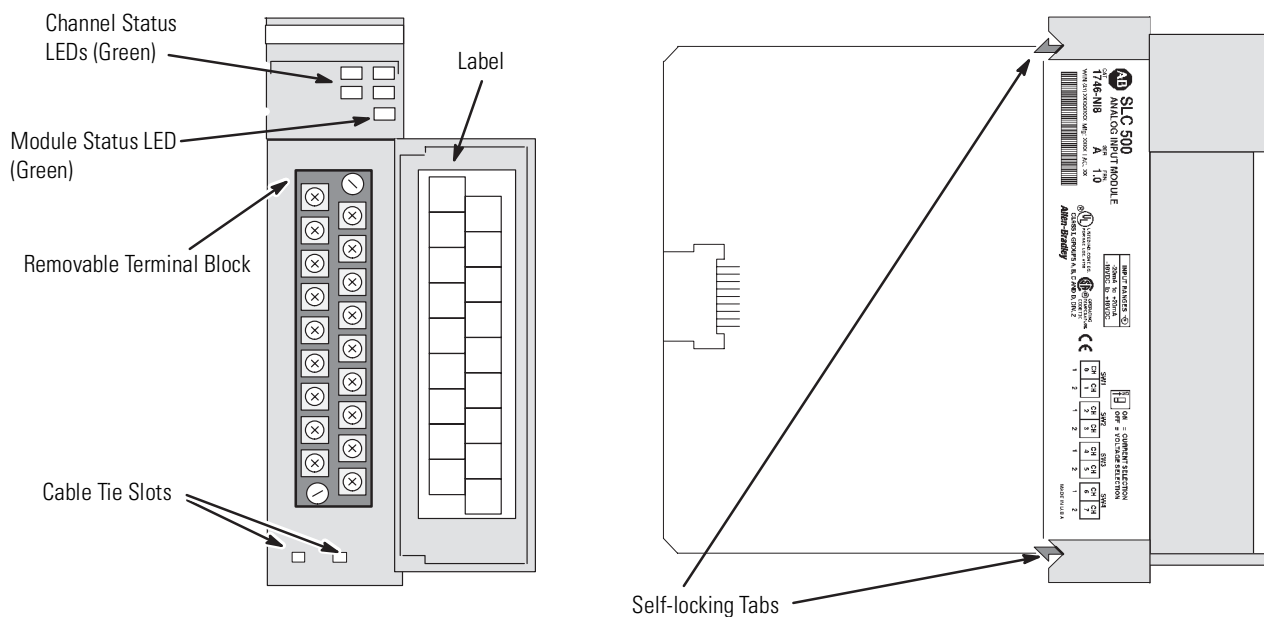
- Engineering Units
- Scaled-for-PID
- Proportional Counts (-32,768 to +32,767 range)
- Proportional Counts with User Defined Range (Class 3 Only)
- 1746-NI4 Data Format

Each input channel also provides open-circuit, out-of-range, and invalid configuration indication via the LED's. These conditions are also displayed in the channel status word.

Hardware Features

The module fits into any slot, except the processor slot (0), in either an SLC 500 modular system or an SLC 500 fixed system expansion chassis (1746-A2).

The module contains a removable terminal block, providing connection for 16 analog input channels, which are specifically designed to interface with analog current and voltage input signals. The channels can only be wired as single-ended inputs. There are no output channels on the module. The module is configured via the user program. The following graphic displays the main hardware features.



| Hardware Feature | Function |
|-------------------------------|--|
| Channel Status LED Indicators | Displays channel operating and fault status. |
| Module Status LED | Displays module operating and fault status. |
| Side Label (Nameplate) | Provides module information. |
| Removable Terminal Block | Provides physical connection to input devices. |
| Door Label | Permits easy terminal identification. |
| Cable Tie Slots | Secures and routes wiring from the module. |
| Self-Locking Tabs | Secures module in the chassis slot. |

General Diagnostic Features

The 1746-NI16 module contains diagnostic features to help identify the source of problems that may occur during power-up or during normal channel operation. These power-up and channel diagnostics are explained in Chapter 6, *Module Diagnostics and Troubleshooting*.

The module communicates to the SLC 500 processor through the parallel backplane interface and receives power from the SLC 500 power supply through the backplane. The +5V dc backplane supply powers the SLC circuitry and the +24V dc backplane supply powers the module analog circuitry. No external power supply is required. You may install as many 1746-NI16 analog modules in a 1746 chassis as the chassis power supply can support.

System Overview

The NI16I can only receive current inputs. The NI16V can only receive voltage inputs.

System Operation

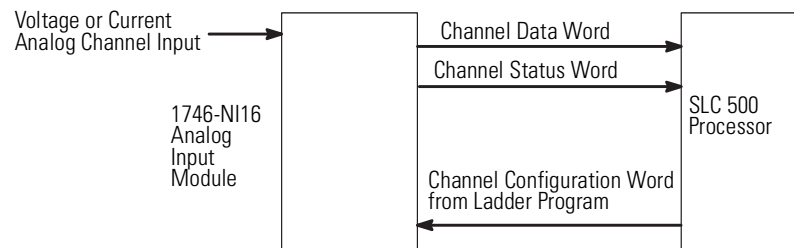
At power-up, the module performs a check of its internal circuits, memory, and basic functions. During this time, the module status LED remains off. If no faults are found during the power-up diagnostics, the module status LED is turned ON.

After power-up checks are complete, the module waits for valid channel configuration data from the SLC ladder logic program (channel status LEDs off). After configuration data is written to one or more channel configuration words and the channel enable status bits are set, the channel status LEDs are turned ON and the module continuously converts the analog input to a value within the range selected in the configuration word.

Each time a channel is read by the module, that data value is tested by the module for a fault condition (i.e., open-circuit, over-range, and under-range). If a fault condition is detected, a unique bit is set in the channel status word and the channel status LED blinks.

The SLC processor reads the converted analog data from the module at the end of the program scan or when commanded by the ladder program. If the processor and module determine that the backplane data transfer was made without error, the data is used in your ladder program. A graphic representation of this is shown below.

Data Transfer Between the Module and Processor (shown for one channel)



Module Operation

The 1746-NI16 module's input circuitry consists of four analog-to-digital (A/D) converters. Each of the 4 A/D converters multiplex 4 inputs for a total of 16 single-ended inputs.

The A/D converters read the selected input signal and convert it to a digital value. The multiplexer sequentially switches each input channel to the module's A/D converter. Multiplexing provides an economical means for a single A/D converter to convert multiple analog signals. However, multiplexing also affects the speed at which an input signal can change and still be detected by the converter.

Module Calibration

The 1746-NI16 module is already factory calibrated and ready for use. Although factory calibration is suitable for most applications, the module can be calibrated by the user. See Appendix D for more information on calibration.

Quick Start for Experienced Users

This chapter can help you to get started using the 1746-NI16 analog input module. The procedures here are based on the assumption that the user has an understanding of SLC 500™ products. The user should understand electronic process control and be able to interpret the ladder logic instructions required to generate the electronic signals that control the application.

Because this chapter is a start-up guide for experienced users, this chapter *does not* contain detailed explanations about the procedures listed. It does, however, reference other chapters in this book where you can get more information about applying the procedures described in each step. It also references other documentation that may be helpful if you are unfamiliar with programming techniques or system installation requirements.

If you have any questions or are unfamiliar with the terms used or concepts presented in the procedural steps, **always read the referenced chapters** and other recommended documentation before trying to apply the information.

This chapter will:

- tell you what equipment you need
- explain how to install and wire the module
- show you how to set up one channel for analog input
- examine the state of the LEDs at normal startup
- examine the channel status word

Required Tools and Equipment

Have the following tools and equipment ready:

- medium blade screwdriver
- medium cross-head screwdriver
- analog input device
- cable for wiring inputs to module
- SLC processor and power supply installed in chassis
- analog input module (1746-NI16)
- programming device and software

Procedures

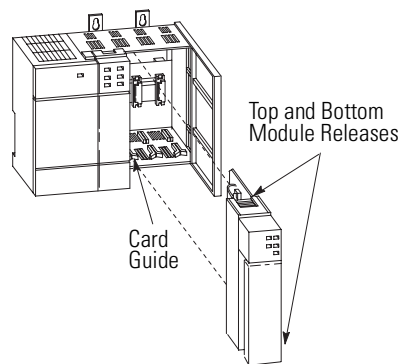
| 1. | Check the contents of shipping box. | Reference |
|---|---|---|
| <p>Unpack the shipping box making sure that the contents include:</p> <ul style="list-style-type: none"> • analog input module (Catalog Number 1746-NI16) • removable terminal block (factory-installed) • Installation Instructions <p>If the contents are incomplete, call your local Allen-Bradley representative for assistance.</p> | | |
| 2. | Ensure that your chassis and power supply support the 1746-NI16 module. | Reference |
| <p>If you are installing the module in a hazardous location, read “Hazardous Location Considerations” on page 3-1. Review the power requirements of your system to ensure that your chassis supports the module:</p> <ul style="list-style-type: none"> • If you are combining a 1746-NI16 module with another I/O module in a fixed controller, refer to the I/O module compatibility table found in Chapter 3. • For modular style systems, calculate the total load on the system power supply using the procedure described in the <i>SLC Installation & Operation Manual for Modular Style Controllers</i> (publication 1747-6.2) or the <i>SLC 500 Family System Overview</i> (publication 1747-2.30). • The 1746-NI16 backplane current consumption is 125 mA at 5V dc and 75 mA at 24V dc. | | <p>Chapter 3 <i>(Installation and Wiring)</i></p> <p>Appendix A <i>(Specifications)</i></p> |

3. Insert the 1746-NI16 module into the chassis.**Reference****ATTENTION**

Never install, remove, or wire modules with power applied to the chassis or devices wired to the module.

Make sure system power is off; then insert the module into your 1746 chassis. In this example procedure, local slot 1 is selected. Any slot may be used except 0.

Chapter 3
(Installation and Wiring)

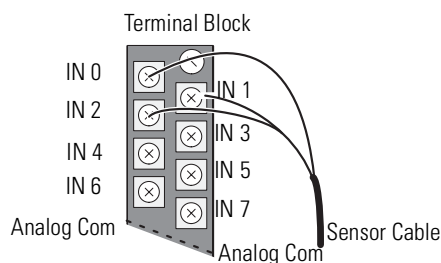
**4. Connect sensor cable.****Reference**

Connect sensor cable to the module's terminal block.

Important: Follow these guidelines when wiring the module:

- Use shielded communication cable (Belden™ 8761) and keep length as short as possible.
- Connect only one end of the cable shield to earth ground.
- Connect all the shields to the earth ground at the SLC 500™ chassis mounting tab.
- Single-ended source commons may be jumpered together at the terminal block.
- Channels are not isolated from each other. All analog commons are connected together internally.
- Common mode voltage range is ± 10.25 volts. The voltage between any two terminals must be less than 20.5 volts.
- The module does not provide power for the analog input transmitters or sensors.
- Use a power supply that matches the transmitter (sensor) specifications.

Chapter 3
(Installation and Wiring)



| 5. Configure the system. | Reference |
|--|--|
| <p>Configure your system I/O for the particular slot the 1746-NI16 is in (slot 1 in this example). Enter the module ID code. The ID code is for Class 1 interface or Class 3 interface. See Chapter 4 for more information on Class 1 and Class 3 interfaces.</p> <p>Important: Not all programming software supports configuration for Class 3 operation.</p> <ul style="list-style-type: none"> • Advanced Programming Software (APS) supports Class 3 configuration, after entering the ID code. • SLC 500 A.I. Series Programming Software supports Class 3 configuration, after entering the ID code. • RSLogix 500, version 1.30 or later, supports Class 3 configuration, after entering the ID code. • Earlier versions of RSLogix 500 only supports configuration for Class 1 operation. Contact Rockwell Software for information on upgrading your software. | <p>Chapter 4 <i>(Preliminary Operating Considerations)</i></p> <p>Appendix C <i>(Converting from 1746-NI4 or 1746-NI8 to 1746-NI16)</i></p> <p>Device's user manual.</p> |

| 6. Determine the operating parameters. | Reference |
|--|---|
| <p>Determine the operating parameters for channel 0. This example shows the channel 0 configuration word. The module is in slot 1. The default configuration word is all zeros.</p> <p>Bit Number</p> <p>Channel 0</p> <ul style="list-style-type: none"> • Class 1, Data or Status Configuration • Class 1 Handshaking • Not Used • Input Type: ± 10 V dc • Data Format: Engineering Units • Calibration • Filter Frequency: 20 Hz • Channel Enable: Enabled | <p>Chapter 4 <i>(Preliminary Opening Considerations)</i></p> <p>Chapter 5 <i>(Channel Configuration, Data and Status)</i></p> <p>Appendix B <i>(1746-NI16 Configuration Worksheet)</i></p> |

| 1746-NI16 Module Output Image - Channel Configuration | | | Class 1 | Class 3 |
|--|-------------------------------|------------------|----------------|----------------|
| 0:1.0 | channel 0 configuration word | bit-mapped field | • | • |
| 0:1.1 | channel 1 configuration word | bit-mapped field | • | • |
| 0:1.2 | channel 2 configuration word | bit-mapped field | • | • |
| 0:1.3 | channel 3 configuration word | bit-mapped field | • | • |
| 0:1.4 | channel 4 configuration word | bit-mapped field | • | • |
| 0:1.5 | channel 5 configuration word | bit-mapped field | • | • |
| 0:1.6 | channel 6 configuration word | bit-mapped field | • | • |
| 0:1.7 | channel 7 configuration word | bit-mapped field | • | • |
| 0:1.8 | channel 8 configuration word | bit-mapped field | | • |
| 0:1.9 | channel 9 configuration word | bit-mapped field | | • |
| 0:1.10 | channel 10 configuration word | bit-mapped field | | • |
| 0:1.11 | channel 11 configuration word | bit-mapped field | | • |
| 0:1.12 | channel 12 configuration word | bit-mapped field | | • |
| 0:1.13 | channel 13 configuration word | bit-mapped field | | • |
| 0:1.14 | channel 14 configuration word | bit-mapped field | | • |
| 0:1.15 | channel 15 configuration word | bit-mapped field | | • |
| 0:1.16 | lower scale limit range 0 | 16-bit integer | | • |
| 0:1.17 | upper scale limit range 0 | 16-bit integer | | • |
| 0:1.18 | lower scale limit range 1 | 16-bit integer | | • |
| 0:1.19 | upper scale limit range 1 | 16-bit integer | | • |
| 0:1.20 | lower scale limit range 2 | 16-bit integer | | • |
| 0:1.21 | upper scale limit range 2 | 16-bit integer | | • |
| 0:1.22 | lower scale limit range 3 | 16-bit integer | | • |
| 0:1.23 | upper scale limit range 3 | 16-bit integer | | • |

| | | |
|-----------|-----------------------------------|------------------|
| 7. | Program the configuration. | Reference |
|-----------|-----------------------------------|------------------|

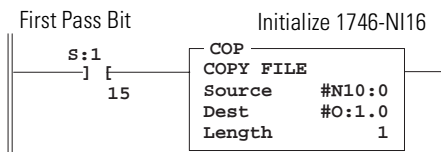
Do the programming necessary to establish the new configuration word setting in the previous step.

1. Create integer file N10. Integer file N10 should contain one element for each channel used. (For this example we only need one, N10:0.)
2. Enter the configuration parameters from step 6 for channel 0 into integer N10:0.
3. Program an instruction in your ladder logic to copy the contents of N10:0 to output word O:1.0.

Chapter 7
(Application Examples)

DATA FILE N10

| | | | | | | | | | | | | | | | | |
|--------|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| Offset | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| N10:0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |



On powerup, the first pass bit (S:1/15) is set for one scan, enabling the MOV instruction that transfers the channel configuration word 0. This configures and enables channel 0.

| | | |
|-----------|----------------------------------|------------------|
| 8. | Write the ladder program. | Reference |
|-----------|----------------------------------|------------------|

Write the remainder of the ladder logic program that specifies how your analog input data is processed for your application. In this procedure the module is located in slot 1.

| | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|--|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Bit Number |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Channel 0 data Word (Variable input data) |

Chapter 5
*(Channel Configuration,
Data and Status)*
Chapter 7
(Application Examples)
Your programming device's
user manual.

1746-NI16 Module Input Image - Data Word

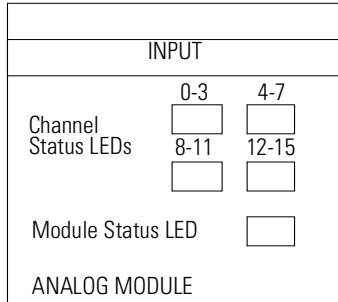
| | | Class 1 ⁽¹⁾ | Class 3 |
|--------|----------------------|---|----------------|
| I:1.0 | Channel 0 data word | 14-bit integer (bits 1 and 0 = 00) ⁽²⁾ | 16-bit integer |
| I:1.1 | Channel 1 data word | 14-bit integer (bits 1 and 0 = 00) ⁽²⁾ | 16-bit integer |
| I:1.2 | Channel 2 data word | 14-bit integer (bits 1 and 0 = 00) ⁽²⁾ | 16-bit integer |
| I:1.3 | Channel 3 data word | 14-bit integer (bits 1 and 0 = 00) ⁽²⁾ | 16-bit integer |
| I:1.4 | Channel 4 data word | 14-bit integer (bits 1 and 0 = 00) ⁽²⁾ | 16-bit integer |
| I:1.5 | Channel 5 data word | 14-bit integer (bits 1 and 0 = 00) ⁽²⁾ | 16-bit integer |
| I:1.6 | Channel 6 data word | 14-bit integer (bits 1 and 0 = 00) ⁽²⁾ | 16-bit integer |
| I:1.7 | Channel 7 data word | 14-bit integer (bits 1 and 0 = 00) ⁽²⁾ | 16-bit integer |
| I:1.8 | Channel 8 data word | 14-bit integer (bits 1 and 0 = 01) ⁽³⁾ | 16-bit integer |
| I:1.9 | Channel 9 data word | 14-bit integer (bits 1 and 0 = 01) ⁽³⁾ | 16-bit integer |
| I:1.10 | Channel 10 data word | 14-bit integer (bits 1 and 0 = 01) ⁽³⁾ | 16-bit integer |
| I:1.11 | Channel 11 data word | 14-bit integer (bits 1 and 0 = 01) ⁽³⁾ | 16-bit integer |
| I:1.12 | Channel 12 data word | 14-bit integer (bits 1 and 0 = 01) ⁽³⁾ | 16-bit integer |
| I:1.13 | Channel 13 data word | 14-bit integer (bits 1 and 0 = 01) ⁽³⁾ | 16-bit integer |
| I:1.14 | Channel 14 data word | 14-bit integer (bits 1 and 0 = 01) ⁽³⁾ | 16-bit integer |
| I:1.15 | Channel 15 data word | 14-bit integer (bits 1 and 0 = 01) ⁽³⁾ | 16-bit integer |

(1) In Class 1, the error is ± 3 LSB of the Class 3 resolution.
 (2) Bits 1 and 0 of the data word are overwritten in Class 1 to indicate data from Channels 0 to 7
 (3) Bits 1 and 0 of the data word are overwritten in Class 1 to indicate data from Channels 8 to 15

| | | |
|-----------|--|------------------|
| 9. | Go through the system start-up procedure. | Reference |
|-----------|--|------------------|

Apply power. Download your program to the SLC 500 processor and put the controller into Run mode. During a normal start up, the module status LED and any enabled channel status LED turn on.

Chapter 6
(Module Diagnostics and Troubleshooting)



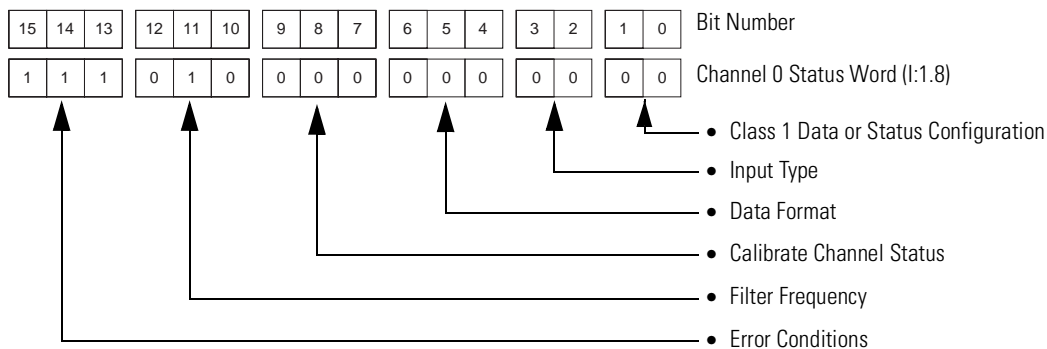
| | | |
|------------|--|------------------|
| 10. | Check that the module is operating correctly. | Reference |
|------------|--|------------------|

(Optional) If the Module Status LED is off, or if the Channel 0 LED is off or blinking, refer to Chapter 6. Class 3 Interface - Monitor the status of input channel 0 to determine its configuration setting and operational status. This is useful for troubleshooting when the blinking channel LED indicates that an error has occurred. The example below shows the Class 3 status word for channel 0 with no errors.

Chapter 5
(Channel Configuration, Data and Status)

Chapter 6
(Module Diagnostics and Troubleshooting)

Chapter 7
(Application Examples)



Installation and Wiring

This chapter tells you how to:

- avoid electrostatic damage
- determine the chassis power requirement for the module
- choose a location for the module in the SLC chassis
- install the module
- wire the module's terminal block
- wire input devices

Hazardous Location Considerations

This equipment is suitable for use in Class I, Division 2, Groups A, B, C, D or non-hazardous locations only. The following ATTENTION statement applies to use in hazardous locations.

ATTENTION**EXPLOSION HAZARD**

- Substitution of components may impair suitability for Class I, Division 2.
 - Do not replace components or disconnect equipment unless power has been switched off.
 - Do not connect or disconnect components unless power has been switched off.
 - This product must be installed in an enclosure.
-

Environnements dangereux

Cet équipement est conçu pour être utilisé dans des environnements de Classe 1, Division 2, Groupes A, B, C, D ou non dangereux. La mise en garde suivante s'applique à une utilisation dans des environnements dangereux.

MISE EN GARDE



DANGER D'EXPLOSION

- La substitution de composants peut rendre cet équipement impropre à une utilisation en environnement de Classe 1, Division 2.
 - Ne pas remplacer de composants ou déconnecter l'équipement sans s'être assuré que l'alimentation est coupée.
 - Ne pas connecter ou déconnecter des composants sans s'être assuré que l'alimentation est coupée.
 - Ce produit doit être installé dans une armoire.
-

Electrostatic Damage

Electrostatic discharge can damage semiconductor devices inside this module if you touch backplane connector pins. Guard against electrostatic damage by observing the following precautions.

ATTENTION



Electrostatic discharge can degrade performance or cause permanent damage. Handle the module as stated below.

- Wear an approved wrist strap grounding device when handling the module.
 - Touch a grounded object to rid yourself of electrostatic charge before handling the module.
 - Handle the module from the front, away from the backplane connector. Do not touch backplane connector pins.
 - Keep the module in its static-shield bag when not in use, or during shipment.
-

1746-NI16 Power Requirements

The 1746-NI16 module receives its power through the SLC 500™ chassis backplane from the fixed or modular +5V dc/+24V dc chassis power supply. The +5V dc backplane supply powers the SLC circuitry, and the +24V dc backplane supply powers the module analog circuitry. The maximum current drawn by the module is shown in the table below.

| 5V dc Amps | 24V dc Amps |
|------------|-------------|
| 0.125 | 0.075 |

When you are using a **modular system** configuration, add the values shown in the table above to the requirements of all other modules in the SLC chassis to prevent overloading the chassis power supply.

When using a **fixed system** controller, see “Fixed Expansion Chassis Considerations” on page 3-3.

Module Location in Chassis Modular Chassis Considerations

Place your 1746-NI16 module in any slot of an SLC 500 modular, or modular expansion chassis, except for the extreme left slot (slot 0) in the first chassis. This slot is reserved for the processor or adapter modules.

ATTENTION



For applications using the upper limit of the operating temperature range, the 1746-NI16 module (or multiple 1746-NI16 modules) should be placed in the right most slot(s) of the chassis. The specification for operating temperature is:

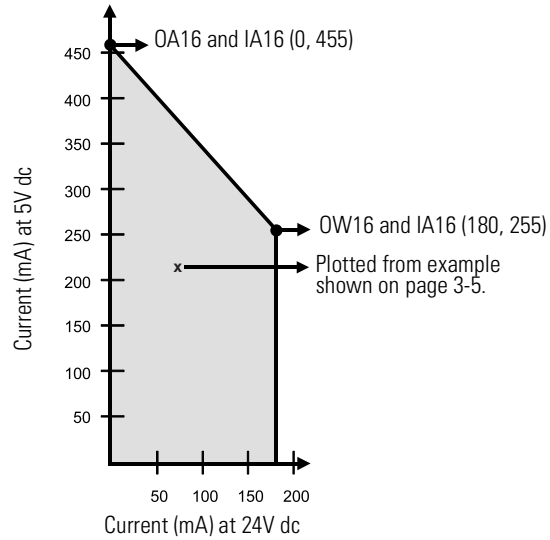
Operating Temperature Range

0°C to 60°C (32°F to 140°F) in any slot except slot 0

Fixed Expansion Chassis Considerations

The chart on page 3-4 depicts the range of current combinations supported by the fixed I/O expansion chassis. To use it, first find the backplane current draw and operating voltage for both of the modules you plan to use in the chassis. The table on page 3-4 shows these specifications.

Next, plot each of the currents on the chart. If the point of intersection falls within the operating region, your combination is valid. If not, your combination cannot be used in a 2-slot, fixed I/O chassis. See the example on page 3-5.



Module Current Draw – Power Supply Loading

| I/O Module | 5V (mA) | 24V (mA) | I/O Module | 5V (mA) | 24V (mA) | I/O Module | 5V (mA) | 24V (mA) |
|----------------|---------|----------|-----------------|---------|----------|----------------|---------|----------|
| BAS | 150 | 40 | IN16 | 85 | 0 | NT4 | 60 | 40 |
| BASn | 150 | 125 | INT4 | 110 | 0 | OA8 | 185 | 0 |
| BLM | 1000 | 0 | IO4 | 30 | 25 | OA16 | 370 | 0 |
| BTM | 110 | 85 | IO8 | 60 | 45 | OAP12 | 370 | 0 |
| DCM | 360 | 0 | IO12 | 90 | 70 | OB6EI | 46 | 0 |
| FIO4I | 55 | 150 | IO12DC | 80 | 60 | OB8 | 135 | 0 |
| FIO4V | 55 | 120 | ITB16 | 85 | 0 | OB16 | 280 | 0 |
| HS | 300 | 0 | ITV16 | 85 | 0 | OB16E | 135 | 0 |
| HSTP1 | 200 | 0 | IV8 | 50 | 0 | OB32, series D | 190 | 0 |
| IA4 | 35 | 0 | IV16 | 85 | 0 | OB32E | 190 | 0 |
| IA8 | 50 | 0 | IV32, series D | 50 | 0 | OBP8 | 135 | 0 |
| IA16 | 85 | 0 | KE | 150 | 40 | OBP16 | 250 | 0 |
| IB8 | 50 | 0 | KE _n | 150 | 125 | OG16 | 180 | 0 |
| IB16 | 85 | 0 | NI4 | 25 | 85 | OV8 | 135 | 0 |
| IB32, series D | 50 | 0 | NI8 | 200 | 100 | OV16 | 270 | 0 |
| IC16 | 85 | 0 | NI16 | 125 | 75 | OV32, series D | 190 | 0 |
| IG16 | 140 | 0 | NIO4I | 55 | 145 | OVP16 | 250 | 0 |
| IH16 | 85 | 0 | NIO4V | 55 | 115 | OW16 | 170 | 180 |
| IM4 | 35 | 0 | NO4I | 55 | 195 | OW4 | 45 | 45 |
| IM8 | 50 | 0 | NO4V | 55 | 145 | OW8 | 85 | 90 |
| IM16 | 85 | 0 | NR4 | 50 | 50 | OX8 | 85 | 90 |

Fixed Chassis Example

The following example shows how to use the chart and table on page 3-4 to determine if the module combination of an 1746-IN16 and 1746-NI16 is supported by the fixed I/O chassis.

1. Find the current draws of both modules in the table.
IN16 = 85 mA at 5V dc and 0 mA at 24V dc
NI16 = 125 mA at 5V dc and 75 mA at 24V dc
2. Add the current draws of both modules at 5V dc.
 $85 \text{ mA} + 125 \text{ mA} = 210 \text{ mA}$
3. Plot this point on the chart above (210 mA at 5V dc).
4. Add the current draws of both modules at 24V dc.
 $0 \text{ mA} + 75 \text{ mA} = 75 \text{ mA}$
5. Plot this point on the chart above (75 mA at 24V dc).

The resulting point of intersection is marked with an “x” on the chart above, showing that this combination falls within the operating region of the fixed I/O chassis.

IMPORTANT

When using the table, be aware that there are certain conditions that affect the compatibility characteristics of the BASIC module (**BAS**) and the DH-485/RS-232C module (**KE**).

When you use the BAS module or the KE module to supply power to a 1747-AIC Link Coupler, the Link Coupler draws its power through the module. The higher current drawn by the AIC at 24V dc is calculated and recorded in the table for the modules identified as **BASn** (BAS networked) or **KE_n** (KE networked). Make sure to refer to these modules if your application uses the BAS or KE module in this way.

General Considerations

Most applications require installation in an industrial enclosure to reduce the effects of electrical interference. Analog inputs are highly susceptible to electrical noise. Electrical noise coupled to the analog inputs reduces the performance (accuracy) of the module.

Group your modules to minimize adverse effects from radiated electrical noise and heat. Consider the following conditions when selecting a slot for the analog input module. Position the module:

- in a slot away from sources of electrical noise such as hard-contact switches, relays, and AC motor drives
- away from modules which generate significant radiated heat, such as the 32-point I/O modules (series C or earlier)

In addition, route shielded analog input wiring away from any high-voltage I/O wiring.

Compliance to European Union Directives

This product is approved for installation within the European Union and EEA regions. It has been designed and tested to meet the following directives.

EMC Directive

The 1746-NI16 analog input module is tested to meet Council Directive 89/336/EEC Electromagnetic Compatibility (EMC) and the following standards, in whole or in part, documented in a technical construction file:

- EN 50081-2
EMC - Generic Emission Standard, Part 2 - Industrial Environment
- EN 50082-2
EMC - Generic Immunity Standard, Part 2 - Industrial Environment

This product is intended for use in an industrial environment.

Module Installation and Removal

When installing the module in a chassis, it is not necessary to remove the terminal block from the module. However, if the terminal block is removed, use the write-on label located on the side of the terminal block to identify the module location and type.



Terminal Block Removal

ATTENTION



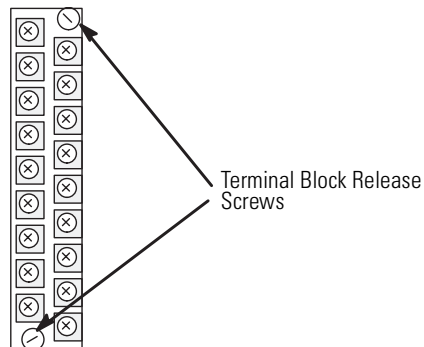
Remove power before removing or inserting this module. When you remove or insert a module with power applied, an electrical arc may occur. An electrical arc can cause personal injury or property damage by:

- sending an erroneous signal to your system's field devices, causing unintended machine motion.
- causing an explosion in a hazardous environment

Electrical arcing causes excessive wear to contacts on both the module and its mating connector. Worn contacts may create electrical resistance.

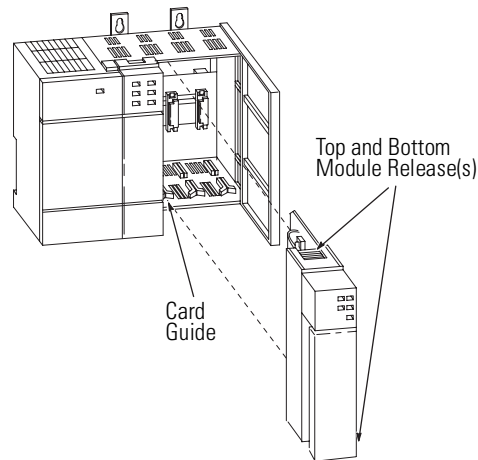
To remove the terminal block:

1. Loosen the two terminal block release screws.
2. Grasp the terminal block at the top and bottom and pull outward and down.



Module Installation Procedure

1. Read the “Module Location in Chassis” section beginning on page 3-3.
2. Align the circuit board of the analog input module with the card guides located at the top and bottom of the chassis.
3. Slide the module into the chassis until both top and bottom retaining clips are secured. Apply firm, even pressure on the module to attach it to its backplane connector. Never force the module into the slot.
4. Cover all unused slots with the Card Slot Filler, catalog number 1746-N2.



Module Removal Procedure

1. Press the releases at the top and bottom of the module and slide the module out of the chassis slot.
2. Cover all unused slots with the Card Slot Filler, catalog number 1746-N2.

Terminal Wiring

The 1746-NI16 module contains an 18-position, removable terminal block. The terminal pin-out is shown below.

ATTENTION

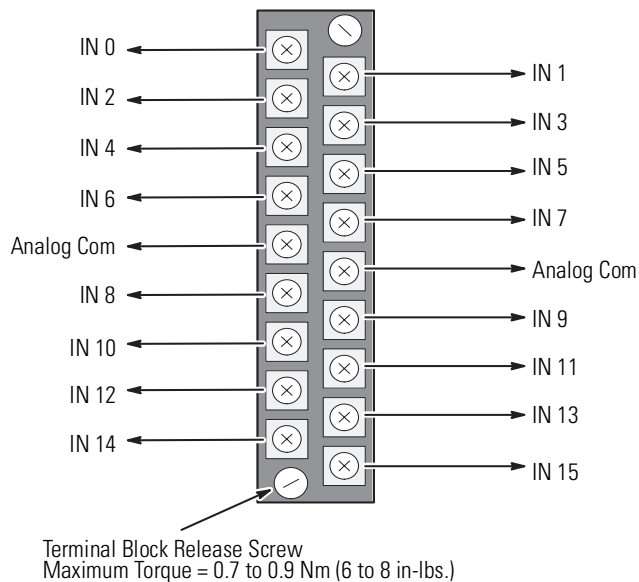


Disconnect power to the SLC before attempting to install, remove, or wire the removable terminal wiring block.

To avoid cracking the removable terminal block, alternate the removal of the slotted terminal block release screws.

Terminal Block

(Terminal Block Spare Part Catalog Number 1746-RT25G)



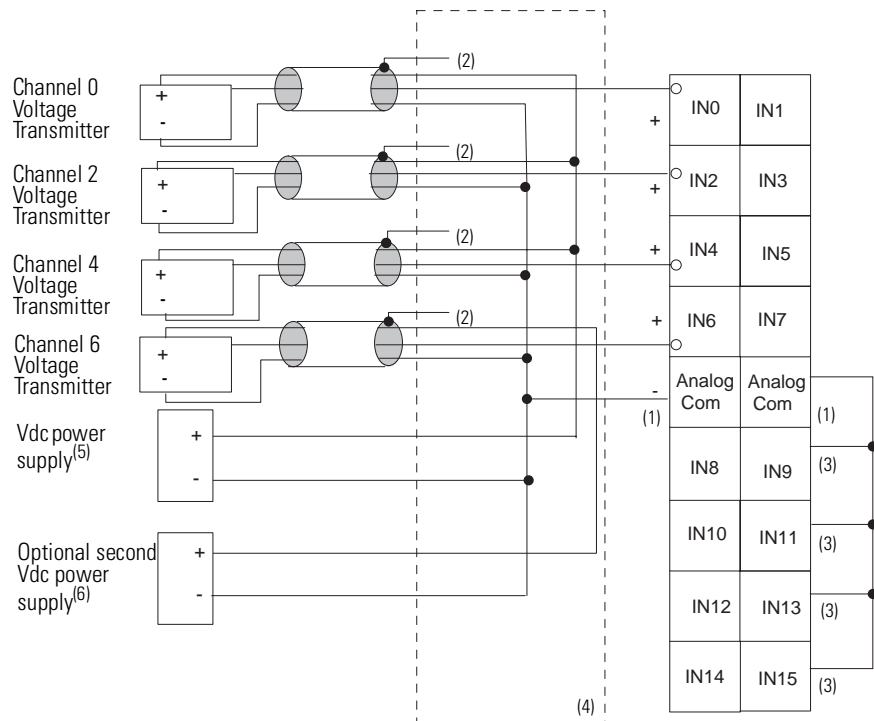
Pre wired Cables and Terminal Blocks

The following 1492 cables and terminal blocks are available to assist in wiring the 1746-NI16 module:

| | |
|------------------------------------|--|
| Allen-Bradley Prewired Cables | 1492-ACAB005A46, 0.5m (1.6 ft.) 1492-ACAB010A46, 1.0 m (3.3 ft.) 1492-ACAB025A46, 2.5 m (8.2 ft.) 1492-ACAB050A46, 5.0 m (16.4 ft.) |
| Allen-Bradley User Terminal Blocks | 1492-AIFM8-3 1492-AIFM16-F-3 |

Wiring Single-Ended Inputs

1746-NI16V

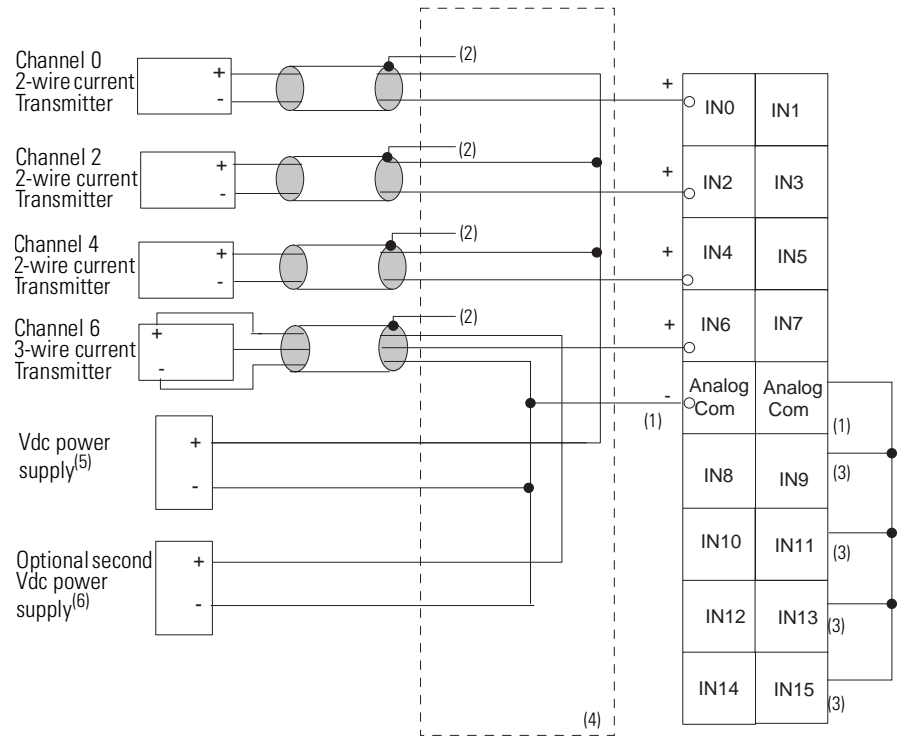


- (1) There are two common terminals for all of the 16 voltage inputs. These two analog common terminals are connected internally.
- (2) All shield wires should be connected to chassis mounting screws.
- (3) Unused channels should be connected to the analog common terminals (0 Volts).
- (4) If separate shielded cables are used for each analog input channel, interposing terminal blocks are needed to terminate up to 16 common wires. Then, 1 to 4 common wires should be wired from the interposing terminal block to the 2 common terminals on the 1746-NI16V module.
- (5) The module does not provide loop power for analog inputs. Use a power supply that matches the transmitter specifications.
- (6) More than one power supply can be used if all supplies are class 2.

NOTE

Although the above diagram has 12 unused inputs, only 4 channels are shown connected to the Analog Com as an example.

1746-NI16I



- (1) There are two common terminals for all of the 16 current inputs. These two analog common terminals are connected internally.
- (2) All shield wires should be connected to chassis mounting screws.
- (3) Unused channels should be connected to the analog common terminals (0 Volts).
- (4) If separate shielded cables are used for each analog input channel, interposing terminal blocks are needed to terminate up to 16 common wires. Then 1 to 4 common wires should be wired from the interposing terminal block to the 2 common terminals on the 1746-NI16I module.
- (5) The module does not provide loop power for analog inputs. Use a power supply that matches the transmitter specifications.
- (6) More than one power supply can be used if all supplies are class 2.

Wiring Guidelines

ATTENTION

To prevent shock hazard, care should be taken when wiring the module to analog signal sources. Before wiring any analog module, disconnect power from the SLC 500 system and from any other source to the analog module.

Follow the guidelines below when planning your system wiring.

- To limit noise, keep signal wires as far away as possible from power and load lines.
- To ensure proper operation and high immunity to electrical noise, always use Belden™ 8761 (shielded, twisted pair) or equivalent wire.
- Connect the shield drain wire to the earth ground of the chassis.
- Tighten terminal screws using a flat or cross-head screwdriver. Each screw should be turned tight enough to immobilize the wire's end. Excessive tightening can strip the terminal screw. The torque applied to each screw should not exceed 0.7 to 0.9 Nm (6 to 8 in-lbs) for each terminal.
- Follow system grounding and wiring guidelines found in your *SLC 500 Modular Hardware Style Installation and Operation Manual*, publication 1747-6.2.

Input Devices

Transducer Source Impedance

If the source impedance of the input device and associated cabling is too high, it affects the accuracy of the channel data word. Source impedance of 2000 ohms produces up to 0.01% of module error over and above the specified accuracy of the module.

You can compensate for device impedance error by implementing the following equation in your ladder program:

$$V_s = V_{measured} \times \frac{(R_s + R_{in})}{R_{in}}$$

where: V_s = input device voltage
 R_s = input device impedance
 R_{in} = 1746-NI16 input impedance (See specifications in Appendix A.)

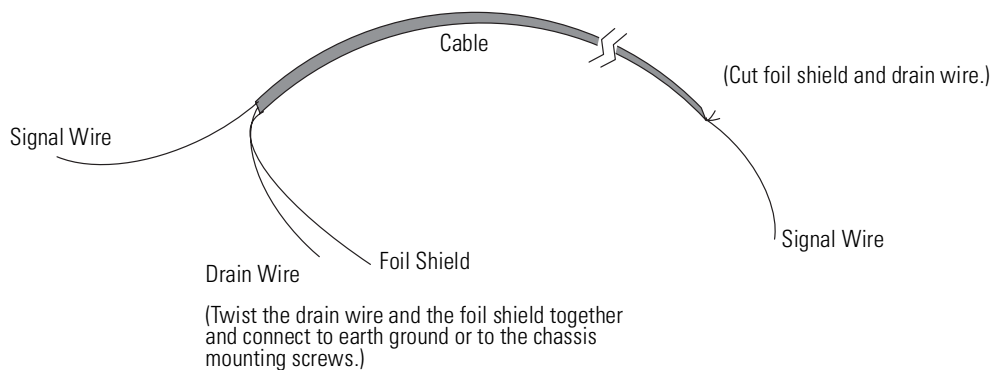
Wiring Input Devices to the 1746-NI16

After the analog input module is properly installed in the chassis, follow the wiring procedure below using Belden™ 8761 cable.

ATTENTION



Care should be taken to avoid connecting a voltage source to a channel configured for current input. Improper module operation or damage to the voltage source can occur.



To wire your 1746-NI16 module follow these steps.

- 1.** At each end of the cable, strip some casing to expose the individual wires.
- 2.** Trim the signal wires to 50 mm (2 in.) lengths. Strip about 5 mm (3/16 in.) of insulation away to expose the end of the wire.
- 3.** At one end of the cable, twist the drain wire and foil shield together.
- 4.** At the other end of the cable, cut the drain wire and foil shield back to the cable.
- 5.** Connect the signal wires to the 1746-NI16 terminal block or interposing terminal block.
- 6.** Connect the shield drain wire to chassis ground.
- 7.** Connect the other end of the cable to the voltage or current transmitter terminals.
- 8.** Repeat steps 1 through 7 for each channel on the module.

Preliminary Operating Considerations

This chapter explains how the analog input module and the SLC 500™ processor communicate through the module's input and output image. It lists the preliminary setup and operation required before the module can function in a 1746 I/O system. Topics discussed include how to:

- enter the module ID code
- select the Class 1 or Class 3 interface
- address your 1746-NI16 module
- select the proper input filter for each channel
- calculate the module update time
- interpret the module response to slot disabling

Module ID Code

The module identification code is a unique number encoded for each 1746 I/O module. The code defines for the processor the type of I/O or specialty module residing in a specific slot in the 1746 chassis.

| Catalog Number | ID Code |
|----------------|---|
| 1746-NI16I | Class 1 interface 3504 Class 3 interface 10403 |
| 1746-NI16V | Class 1 interface 3505 Class 3 interface 10406 |

NOTE Not all programming software supports configuration for Class 3 operation.

- Advanced Programming Software (APS) supports Class 3 configuration. After entering the ID code (NI16I - 10403, NI16V - 10406), enter 32 input words and 32 output words.
- SLC 500 A.I. Series™ Programming Software supports Class 3 configuration. After entering the ID code (NI16I - 10403, NI16V - 10406), enter 32 input words and 32 output words.
- RSLogix 500™, version 1.30 or later, supports Class 3 configuration. After entering the ID code (NI16I - 10403, NI16V - 10406), select Class 3 operation.
- Earlier versions of RSLogix 500 only support configuration for Class 1 operation. Contact Rockwell Software for information on upgrading your software.

Class 1 and Class 3 Interface

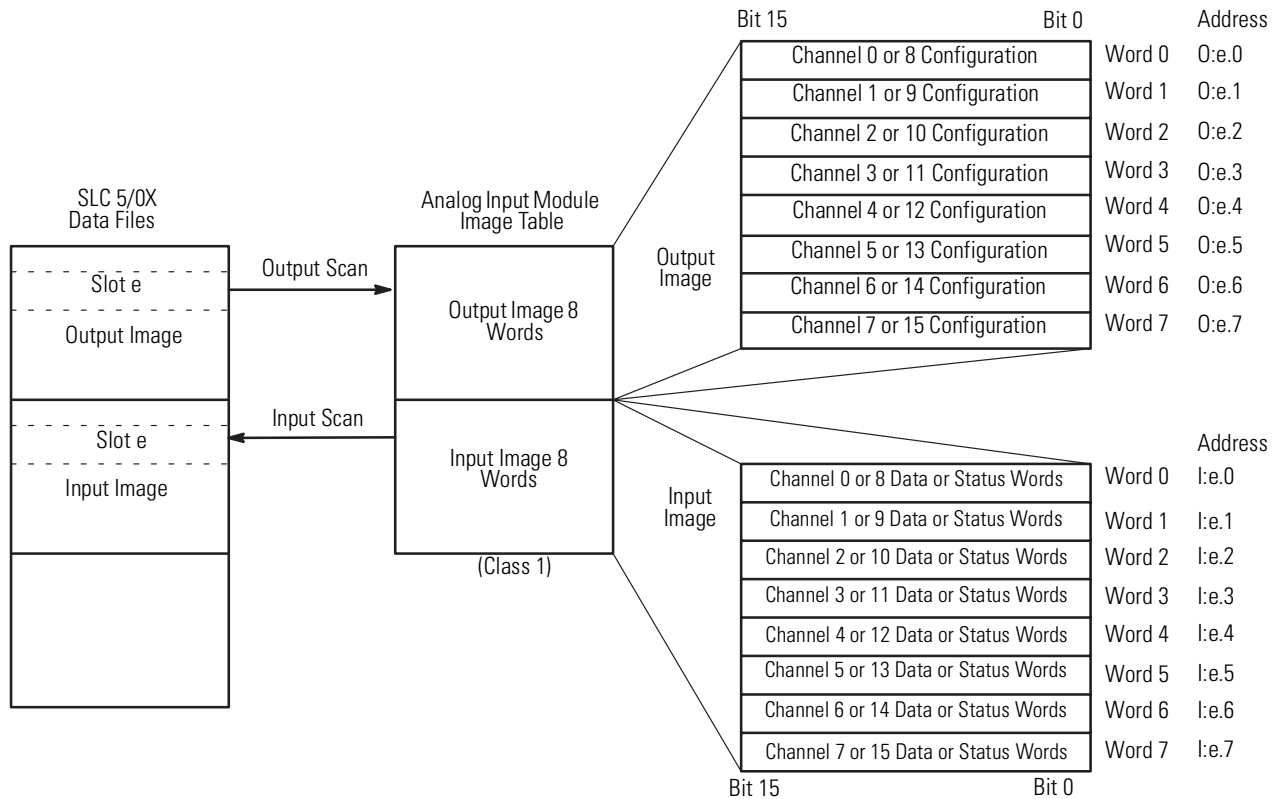
The 1746-NI16 analog input module has multi-class interface capabilities. Class 1 is the default configuration. The module can be configured through the user program for Class 3, which enables user-defined data scaling and monitoring of channel status words. Use Class 3 operation whenever possible.

| Configuration | Class 1 | Class 3 |
|---------------------------|---|---|
| Compatible SLC Processors | SLC 500 fixed, SLC 5/01, SLC 5/02, SLC 5/03, SLC 5/04 and SLC 5/05 | SLC 5/02, SLC 5/03, SLC 5/04 and SLC 5/05 |
| Compatible Chassis | local chassis or remote chassis with a 1747-ASB module | local chassis or remote ControlNet chassis with a 1747-ACN(R) module |
| Input and Output Images | output image: 8 words available for configuring 16 channels input image: 8 words available for 16 data words and 16 status words | output image: 24 words available for configuring all 16 channels input image: 32 words available for 16 data words and 16 status words |
| Default | Class 1 is the default on power-up | Class 3 is programmable by user |

Module Addressing

The following memory maps show you how the input image and output image tables are defined for Class 1 and Class 3.

Class 1 Memory Map

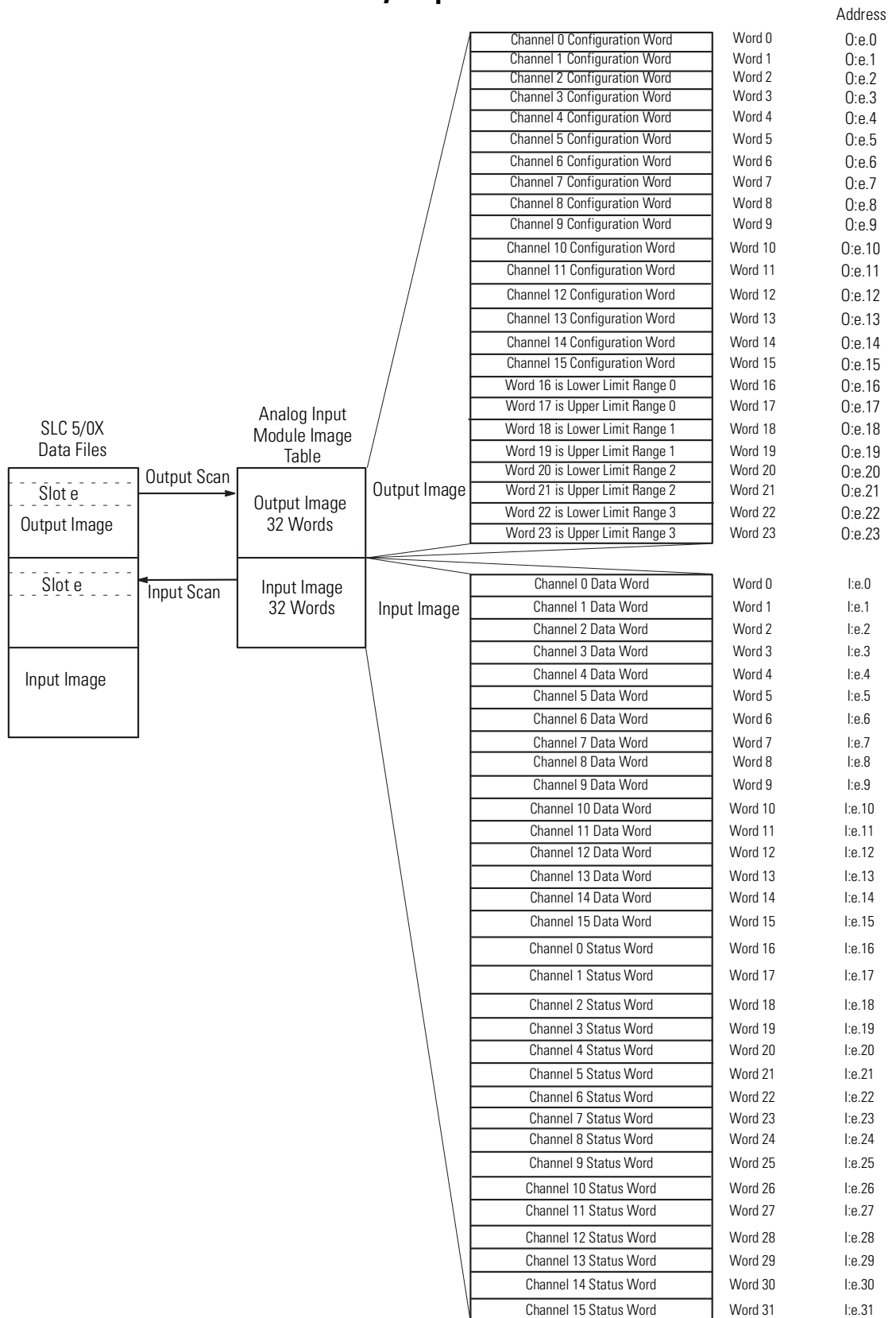


NOTE

The 8 output image words can either configure channels 0 to 7 or 8 to 15 depending on how bit 0 is set.

The 8 input image words show either data or status for channels 0 to 7 or 8 to 15. Bits 0 and 1 in the configuration word determine whether status or data is shown.

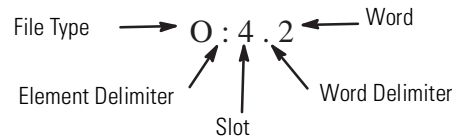
Class 3 Memory Map



Output Image - Configuration Words

The module output image (defined as the output from the processor to the module) contains information that you configure to define the way a specific module channel works. Each output word configures a single channel.

Example - If you want to configure channel 2 on the analog module located in slot 4 in the chassis, your address would be O:4.2.



Chapter 5, *Channel Configuration, Data, and Status*, gives you detailed bit information about the data content of the configuration word. Also, see Chapter 7 for a detailed explanation and application examples.

Input Image - Data Words and Status Words

The input image (defined as the input word from the module to the processor) represents data words and status words.

Input words hold the input data that represent the value of analog inputs for channels 0-15. This data word is valid only when the channel is enabled and there are no channel errors.

Class 1 Input Words - Data

The data words for Class 1 are input words 0 through 7. Setting bits 1 and 0 in the output configuration word to 00 or 01 returns the data for channels 0 through 7 or 8 through 15, respectively. Class 1 data mode only returns a 14-bit integer ± 3 LSB of the Class 3 resolution. The remaining 2 bits, bits 1 and 0, indicate whether the input word is data or status for channels 0 through 7 or 8 through 15.

Class 3 Input Words - Data

The data words for Class 3 are the input words 0 through 15. Data for all 16 channels can be viewed simultaneously, and all data words are 16-bit integer values.

Input words also contain the status of channels 0 through 15. The status bits for a particular channel reflect the configuration settings that you entered into the output image configuration word for that

channel and provide information about the channel's operational state. To receive valid status information, the channel must be enabled, and the channel must have processed any configuration changes that may have been made to the configuration word.

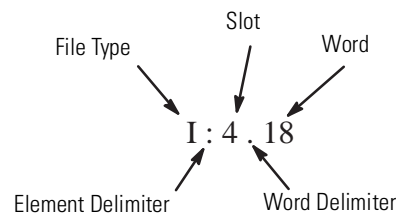
Class 1 Input Words - Status

The status words for Class 1 are the input words 0 through 8. Setting bits 1 and 0 in the output configuration word to 10 or 11 returns status for channels 0 through 7 or 8 through 15, respectively.

Class 3 Input Words - Status

The status words for Class 1 are the input words 16 through 31. Status for all 16 channels can be viewed at the same time as data for all 16 channels.

Class 3 Example - To obtain the status of channel 2 (input word 18) of the analog module located in slot 4 in the SLC chassis, use address I:4.18.

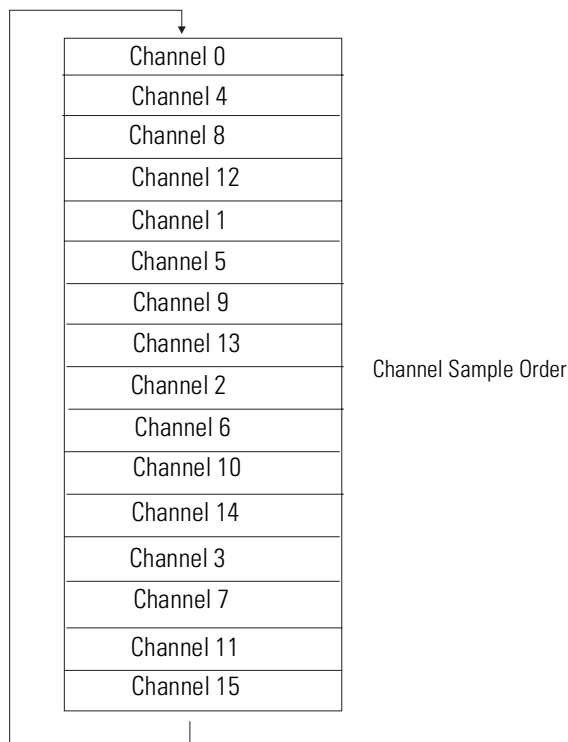


Chapter 5, *Channel Configuration, Data, and Status*, gives you detailed bit information about the content of the data word and the status word. Also, see Chapter 7 for a detailed explanation and application examples.

Module Update Time

The module update time is defined as the time required for the module to sample and convert the input signals of all enabled input channels and provide the resulting data values to the SLC 500 processor. For the most part, the module update time depends on the filter setting. Lower filter frequencies can be selected to reject noise. However, as noise rejection improves, module update time increases. Choose the lowest filter frequency consistent with how quickly your program requires fresh analog data.

The 1746-NI16 module sequentially samples the channels in a continuous loop according to the following diagram. The next channel in the order is sampled if any channel is disabled.



The following table shows the module update time. The module update time is different depending on the number of channels enabled and filter frequency. The fastest module update time occurs when only one channel is enabled on each A/D chip (channels 0, 4, 8, and 12). The slowest module update time occurs when 16 channels are enabled.

| Filter Frequency (Hz) | Update Time 16-Ch (ms)⁽¹⁾ | Update Time 12-Ch (ms)⁽¹⁾ | Update Time 8-Ch (ms)⁽¹⁾ | Update Time 4-Ch (ms)⁽¹⁾ |
|------------------------------|---|---|--|--|
| 6 | 630 | 473 | 314 | 7 |
| 10 | 380 | 285 | 190 | 4 |
| 20 | 194 | 145 | 96 | 4 |
| 40 | 100 | 75 | 50 | 4 |
| 60 | 69 | 52 | 34 | 4 |
| 80 | 54 | 39 | 26 | 4 |
| 100 | 37 | 27 | 18 | 4 |
| 250 | 18 | 13 | 9 | 4 |

⁽¹⁾ Assuming all of the enabled channels have the filter frequency shown in the first column.

The hardware architecture has some bearing on how the module firmware works and thus how a user can optimize performance when fewer than all 16 channels are required. You can enable any number of channels you want, but certain channel selections make data available to your ladder program more quickly than others.

The module uses four A/D converters, each multiplexing four input channels. The first A/D is for channels 0 through 3, the second for 4 through 7, and so forth. Although there is room in the configuration data table to select a different filter for each channel, the filter value programmed for the first channel of each A/D is used for all four channels of that A/D. In other words, the filter selection made for channel 0 is used for channels 0 through 3. The selection programmed for channel 4 is applied to channels 4 through 7, and so forth.

If your application requires 12 or fewer of the 16 analog inputs, you can achieve a module update time of about 3/4 of the time listed in the table above for 16 channels if you enable channels in a certain way. Use the first three channels on each A/D, leaving the fourth channel disabled. For example, if you enable channels 0, 1, 2, 4, 5, 6, 8, 9, 10, 12, 13, and 14, your module update time is about 75 ms with the 40 Hz filter instead of 100 ms listed in the table if all 16 inputs are enabled.

Similarly, if you need 8 or fewer channels, you can achieve a module update time of about one-half the 16-channel table values. For example, if you enable only channels 0, 1, 4, 5, 8, 9, 12, 13, the module update time is about 50 ms with a 40 Hz filter.

Finally, for very fast response you may use four or fewer channels. This mode exploits the power of dedicating one A/D converter per channel. The A/Ds are considerably faster when they do not have to multiplex inputs.

NOTE

In this mode, the module provides four channels of data every 4 ms, regardless of filter setting.

NOTE

The same channels are used on each of the four A/D converters. In the 12-or-fewer-channels example above, note that you are using channels 0, 1, and 2 on each of the four A/D converters, but channel 3 on each remains disabled. If you just enable the first 12 channels (0 to 11) on the module, and leave channels 12 to 15 disabled, your update time is the same as if you had enabled all 16 channels.

Channel Filter Frequency Selection

The module uses a digital low-pass filter that provides noise rejection for the input signals. The digital filter is programmable, allowing you to select from eight filter frequencies for each group of four channels.

Selecting a low value (i.e., 6 Hz) for the channel filter frequency provides the best noise rejection for that group of channels. Selecting a high value for the channel filter frequency provides less noise rejection, but faster data response time. See page 4-10 for more information on noise rejection.

The table on page 4-7 shows the available filter frequencies and module data update times for each filter frequency

Channel Frequency

Channel Cut-Off Frequency

The channel filter frequency selection determines a channel's cut-off frequency, also called the -3 dB frequency. The cut-off frequency is defined as the point on the input channel frequency response curve where frequency components of the input signal are passed with 3 dB of attenuation. All frequency components at or below the cut-off frequency are passed by the digital filter with less than 3 dB of attenuation. All frequency components above the cut-off frequency are increasingly attenuated.

The cut-off frequency for each input channel is defined by its filter frequency selection. Choose a filter frequency so that your fastest changing signal is below that of the filter's cut-off frequency. The cut-off frequency should not be confused with update time. The cut-off frequency relates how the digital filter attenuates frequency components of the input signal. The update time defines the rate at which an input channel is scanned and its channel data word is updated.

Aliasing Frequency

Aliasing is a natural characteristic of discrete time sampling of analog signals. This can result in erroneous data in the data channel word. Aliasing is usually not a problem because the duration of the high-frequency signal is much shorter than the program scan time.

Aliasing begins at a lower frequency when more channels are enabled. Anti-aliasing filters are available, but you should check your transducer for malfunctions first, as the filters are fairly expensive.

Aliasing occurs when unwanted signals, at a frequency greater than the effective sampling rate, are present. The effective sampling rate is determined by the number of enabled channels (n). The first aliasing frequency occurs at: $f_a = (1 / \text{Update Time in seconds})$. Subsequent aliasing frequencies occur at integer multiples of f_a .

Noise Rejection

Rejection of common mode noise is inherent in the hardware design of the module. Common mode rejection is better than -100 dB for common mode 50 Hz and 60 Hz AC signals. The module performs well in the presence of common mode noise as long as the signals applied to the user terminals do not exceed the common mode voltage rating (± 10.25 Volts) of the module. Improper earth/chassis ground connections may be a source of common mode noise.

Rejection of normal mode noise is implemented in the firmware and is a function of the filter frequency selected by the user. A lower frequency filter rejects more normal mode noise than a higher frequency filter. Transducer power supply noise, transducer circuit noise, or process variable irregularities may be sources of normal mode noise.

Response to Slot Disabling

By writing to the status file in your modular SLC processor you can disable any chassis slot. Refer to your programming device's manual for the slot disable/enable procedure.

ATTENTION



Always consider the implications of disabling a module before using the slot disable feature.

Input Response

When a slot is disabled, the 1746-NI16 module continues to update its input image table. However, the SLC processor does not read inputs from a module that is disabled. Therefore, when the processor disables the module slot, the module inputs appearing in the processor image table remain in their last state and the module's updated image table is not read. When the processor re-enables the module slot, the current state of the module inputs are read by the processor during the subsequent scan.

Output Response

The SLC 500 processor may change the module output data (configuration) as it appears in the processor output image. However, this data is not transferred to the module. The outputs are held in their last state. When the slot is re-enabled, the current data in the processor image is transferred to the module.

Channel Configuration, Data, and Status

This chapter examines the channel configuration word and the channel status word bit by bit and explains how the module uses configuration data and generates status during operation. It gives you information about how to:

- configure a channel
- scale the channel data
- check a channel's status

Channel Configuration

The channel configuration word is a part of the 1746-NI16 module's output image as shown below. The module output image uses 8 words when the module is in Class 1 mode and 32 words when the module is in Class 3 mode. A description of the output image is shown below.

| 1746-NI16 Module Output Image - Channel Configuration | | | Class 1 | Class 3 |
|---|-------------------------------|------------------|---------|---------|
| 0:e.0 | channel 0 configuration word | bit-mapped field | • | • |
| 0:e.1 | channel 1 configuration word | bit-mapped field | • | • |
| 0:e.2 | channel 2 configuration word | bit-mapped field | • | • |
| 0:e.3 | channel 3 configuration word | bit-mapped field | • | • |
| 0:e.4 | channel 4 configuration word | bit-mapped field | • | • |
| 0:e.5 | channel 5 configuration word | bit-mapped field | • | • |
| 0:e.6 | channel 6 configuration word | bit-mapped field | • | • |
| 0:e.7 | channel 7 configuration word | bit-mapped field | • | • |
| 0:e.8 | channel 8 configuration word | bit-mapped field | | • |
| 0:e.9 | channel 9 configuration word | bit-mapped field | | • |
| 0:e.10 | channel 10 configuration word | bit-mapped field | | • |
| 0:e.11 | channel 11 configuration word | bit-mapped field | | • |
| 0:e.12 | channel 12 configuration word | bit-mapped field | | • |
| 0:e.13 | channel 13 configuration word | bit-mapped field | | • |
| 0:e.14 | channel 14 configuration word | bit-mapped field | | • |
| 0:e.15 | channel 15 configuration word | bit-mapped field | | • |
| 0:e.16 | lower limit range 0 | 16-bit integer | | • |
| 0:e.17 | upper limit range 0 | 16-bit integer | | • |
| 0:e.18 | lower limit range 1 | 16-bit integer | | • |
| 0:e.19 | upper limit range 1 | 16-bit integer | | • |
| 0:e.20 | lower limit range 2 | 16-bit integer | | • |
| 0:e.21 | upper limit range 2 | 16-bit integer | | • |
| 0:e.22 | lower limit range 3 | 16-bit integer | | • |
| 0:e.23 | upper limit range 3 | 16-bit integer | | • |

After installation, each channel must be configured to establish the way the channel operates. You configure the channel by entering bit values into the configuration word using your programming device. A bit-by-bit examination of the configuration word is provided in the chart on page 5-3. Programming is discussed in Chapter 7. Addressing is explained in Chapter 4.

The configuration word default setting is all zeros.

Output Image Channel Configuration Procedure

The channel configuration word consists of bit fields, the settings of which determine how the channel operates. See the chart on the following page and the descriptions that follow for configuration information. Appendix B contains a configuration worksheet.

After determining the configuration for each channel, follow the steps outlined in Chapter 2, Quick Start, or in Chapter 7, Application Examples, to enter this configuration data into your ladder program and copy it to the 1746-NI16 module.

Channel Configuration Word

| Define | To Select | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--|---|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| Class 1 Data or Status Configuration | Read Data for Channel 0 to 7 | | | | | | | | | | | | | | | 0 | 0 |
| | Read Data for Channel 8 to 15 | | | | | | | | | | | | | | | 0 | 1 |
| | Read Status for Channel 0 to 7 | | | | | | | | | | | | | | | 1 | 0 |
| | Read Status for Channel 8 to 15 | | | | | | | | | | | | | | | 1 | 1 |
| Class 1 Handshaking | To Reset Status Bit 6 | | | | | | | | | | | | | | 0 | | |
| | Transmit Channel Configuration | | | | | | | | | | | | | | 1 | | |
| Reserved | Not Used | | | | | | | | | | | | | X | | | |
| Input Type | +/- 10 Vdc or +/- 20 ma | | | | | | | | | | | 0 | 0 | | | | |
| | 1 to 5 Vdc or 4 to 20 ma | | | | | | | | | | | 0 | 1 | | | | |
| | 0 to 5 Vdc or 0 to 1 ma | | | | | | | | | | | 1 | 0 | | | | |
| | 0 to 10 Vdc or 0 to 20 ma | | | | | | | | | | | 1 | 1 | | | | |
| Data Format | Engineering Units | | | | | | | | 0 | 0 | 0 | | | | | | |
| | Scaled-for-PID | | | | | | | | 0 | 0 | 1 | | | | | | |
| | Proportional Counts | | | | | | | | 0 | 1 | 0 | | | | | | |
| | 1746-NI4 Data Format | | | | | | | | 0 | 1 | 1 | | | | | | |
| | User Limit Range 0 (Class 3 Only) | | | | | | | | 1 | 0 | 0 | | | | | | |
| | User Limit Range 1 (Class 3 Only) | | | | | | | | 1 | 0 | 1 | | | | | | |
| | User Limit Range 2 (Class 3 Only) | | | | | | | | 1 | 1 | 0 | | | | | | |
| | User Limit Range 3 (Class 3 Only) | | | | | | | | 1 | 1 | 1 | | | | | | |
| Calibration Channel needs to be disabled to perform calibration | Normal RUN Mode (Exit Calibration Mode) | | | | | 0 | 0 | 0 | | | | | | | | | |
| | Enter Calibration Mode | | | | | 0 | 0 | 1 | | | | | | | | | |
| | Perform Zero Calibration | | | | | 0 | 1 | 1 | | | | | | | | | |
| | Perform Full Scale Calibration | | | | | 1 | 0 | 1 | | | | | | | | | |
| Filter Frequency Filter frequencies are set in ch 0, 4, 8 and 12 for that channel and the following 3 channels in that group. Filter groupings are: (0 to 3) (4 to 7) (8 to 11) and (12 to 15) | 6 Hz | | 0 | 0 | 0 | | | | | | | | | | | | |
| | 10 Hz | | 0 | 0 | 1 | | | | | | | | | | | | |
| | 20 Hz | | 0 | 1 | 0 | | | | | | | | | | | | |
| | 40 Hz | | 0 | 1 | 1 | | | | | | | | | | | | |
| | 60 Hz | | 1 | 0 | 0 | | | | | | | | | | | | |
| | 80 Hz | | 1 | 0 | 1 | | | | | | | | | | | | |
| | 100 Hz | | 1 | 1 | 0 | | | | | | | | | | | | |
| | 250 Hz | | 1 | 1 | 1 | | | | | | | | | | | | |
| Channel Enable | Channel Disabled | 0 | | | | | | | | | | | | | | | |
| | Channel Enabled | 1 | | | | | | | | | | | | | | | |

Select Channel Enable (Bit 15)

Determine which channels are used in your program and enable them. Place a 1 in bit 15 to enable a channel. Place a 0 in bit 15 to disable the channel. In class 1, only the handshake bit (bit 2) needs to be set to transmit this configuration bit change.

The 1746-NI16 only samples data from channels that are enabled. To optimize module operation and minimize throughput times, **disable unused channels** by setting the channel enable bit to 0.

When the channel enable bit is set (1), the module reads the configuration word information you have selected. While the enable bit is set, modification of the configuration word may lengthen the module update time for one cycle. If any change is made to the configuration word, the change must be reflected in the status word before new data is valid.

While the channel enable bit is cleared (0), the channel data word and status word values are cleared. After the channel enable bit is set (1), the channel data word and status word remain cleared until the module sets the channel status bits (bits 15, 14, and 13 to 1, 1, and 1) in the channel status word, signifying that the channel is operating without an error. See “Channel Status Checking” on page 5-16.

Select Channel Filter Frequency (Bits 14 through 12)

The 1746-NI16 module features eight different filter frequencies. Choose the desired filter by entering the 3-digit binary code in bits 12 through 14 of the channel configuration word. You can select a different filter setting for each A/D chip. Each chip samples a group of 4 input channels. The groups of A/D inputs are shown in the table on page 5-5.

The filter selection for all of the channels in a group is selected using the configuration word of the first channel in each group. These channels are channels 0, 4, 8, and 12. Even if the first channel in each group is disabled, the desired filter frequency must be selected in that channel's configuration word; otherwise, the default filter frequency of 6Hz is used. Setting the filter frequency in the other channels (1 to 3, 5 to 7, 9 to 11, or 13 to 15) will not select a filter. Instead, the default filter is selected.

The default filter setting is 6 Hz. The default filter setting is the bit pattern (0, 0, 0) in bits 14 through 12.

| A/D Groups | Channels in A/D Group | How to select Filter Frequencies for the different A/D Groups |
|-------------------|--|---|
| Group 1 | Channel 0 Channel 1 Channel 2 Channel 3 | Filter selection for all the channels in group 1 is done in the configuration word for channel 0. Even if channel 0 is disabled, the filter setting needs to be selected in channel 0 for the rest of the channels in group 1. Setting the filter in channels 1-3 will not select a filter, rather the default filter is selected. |
| Group 2 | Channel 4 Channel 5 Channel 6 Channel 7 | Filter selection for all the channels in group 2 is done in the configuration word for channel 4. Even if channel 4 is disabled, the filter setting needs to be selected in channel 4 for the rest of the channels in group 2. Setting the filter in channels 5-7 will not select a filter, rather the default filter is selected. |
| Group 3 | Channel 8 Channel 9 Channel 10 Channel 11 | Filter selection for all the channels in Group 3 is done in the configuration word for channel 8. Even if channel 8 is disabled, the filter setting needs to be selected in channel 8 for the rest of the channels in group 3. Setting the filter in channels 9-11 will not select a filter, rather the default filter is selected. |
| Group 4 | Channel 12 Channel 13 Channel 14 Channel 15 | Filter selection for all the channels in Group 4 is done in the configuration word for channel 12. Even if channel 12 is disabled, the filter setting needs to be selected in channel 12 for the rest of the channels in group 4. Setting the filter in channels 13-15 will not select a filter, rather the default filter is selected. |

The filter frequency affects the noise rejection characteristics. A lower filter frequency increases noise rejection, and a higher filter frequency decreases noise rejection. Select a filter frequency considering acceptable noise and step response time. See “Channel Filter Frequency Selection” on page 4-9 for more information on filter frequency.

Select Calibration Mode (Bits 11 through 9)

To enter the calibration routine, set bit 9 to 1. You must perform the low calibration first and then the high calibration to successfully calibrate the module.

Low Calibration

Short channel input to analog common terminal. Then, set bit 10 of the channel to be calibrated to 1. Clear bit 10 when completed.

High Calibration

Apply +10.25V dc \pm 200 μ V or +21 mA \pm 200 nA between channel input and analog common. Then, set bit 11 of the channel to be calibrated to 1. Clear bits 11 and 9 when completed.

Select Data Format (Bits 8 through 6)

Select a data format for the data word value. Your selection determines how the analog input value from the A/D converter is expressed in the data word. Enter your 3-digit binary code in bit fields 8 through 6 of the channel configuration word. The data types are:

- Engineering Units
- Scaled-for-PID
- Proportional Counts
- 1746-NI4 Data Format
- User-defined Scaling (Class 3 Only)

For all data types, the channel data word is proportional to the analog input signal.

To have the data in “real” units, the channel data word must be scaled mathematically. See “Input Image - Channel Data Word” on page 5-8 for the default scaling values and “Scaling the Channel Data Word” on page 5-10 for data type descriptions and scaling examples.

Select Input Type (Bits 5 and 4)

The input type bit field lets you configure the channel for the type of input device you have connected to the module. Valid input is an analog voltage or current that provides a signal within one of the specified ranges.

Determine the input device type for a channel and enter its respective 2-digit binary code in bit fields 5 and 4 of the channel configuration word.

Unused Bit (Bit 3)

Bit 3 is not used on the 1746-NI16I or 1746-NI16V modules. Ensure this bit is always set to zero, or the module returns a configuration error in the status word for that channel.

Class 1 Handshaking (Bit 2)

In Class 1, the module provides handshaking to simplify configuration. This handshaking feature is the fastest way to configure the module's 16 channels. To transmit a channel's configuration, bit 2 should be set to 1. When the module has completed this instruction, a 1 is placed in bit 6 of the status word. To reset bit 6 of the status word to 0, reset bit 2 in the configuration word to 0. After channels 0 through 7 are configured, then channels 8 through 15 can be configured. An application example for Class 1, using bits 2 and 6 to perform configuration handshaking for all 16 channels, can be found on page 7-1. The handshaking between bits 2 and 6 is not needed in Class 3 since all 32 words of data and status can be sent and received at once.

Class 1 Data or Status Configuration (Bits 1 and 0)

Bits 1 and 0 are only used in Class 1 mode. If these bits are set while in Class 3 mode, a configuration error is set in the status word (bits 15, 14 and 13 set to 0, 1, and 1). The use of these bits is not necessary in Class 3 because Class 3 allows for data transfer of a 32-word block. In Class 1 mode, data transfer is limited to 8-word blocks. The 1746-NI16 has the ability to communicate 16 words of data and 16 words of status information. Therefore, the user can choose which block of 8 words is needed via bits 1 and 0 in the configuration word. This is done in the following manner:

| Set Bit 0 to: | to select channels: | Set Bit 1 to: | to select: |
|---------------|---------------------|---------------|--------------------|
| 0 | 0 through 7 | 0 | data |
| 1 | 8 through 15 | 1 | status information |

NOTE

For a description of data reporting in the status word, see "Input Word Bit Definitions" on page 5-20.

Input Image - Channel Data Word

The module input image uses 8 data word values in Class 1 and 16 data word values in Class 3. The converted voltage or current input data values reside in I:e.0 through I:e.7 (Class 1) or I:e.0 through I:e.15 (Class 3) of the module's input image file. When an input channel is disabled, its data word is reset to zero.

| Class 1 Data Word | | | Bit 1 set to ⁽¹⁾ | Bit 0 set to ⁽¹⁾ |
|-------------------|----------------------|----------------|-----------------------------|-----------------------------|
| I:e.0 | channel 0 data word | 14-bit integer | 0 | 0 |
| I:e.1 | channel 1 data word | 14-bit integer | 0 | 0 |
| I:e.2 | channel 2 data word | 14-bit integer | 0 | 0 |
| I:e.3 | channel 3 data word | 14-bit integer | 0 | 0 |
| I:e.4 | channel 4 data word | 14-bit integer | 0 | 0 |
| I:e.5 | channel 5 data word | 14-bit integer | 0 | 0 |
| I:e.6 | channel 6 data word | 14-bit integer | 0 | 0 |
| I:e.7 | channel 7 data word | 14-bit integer | 0 | 0 |
| I:e.0 | channel 8 data word | 14-bit integer | 0 | 1 |
| I:e.1 | channel 9 data word | 14-bit integer | 0 | 1 |
| I:e.2 | channel 10 data word | 14-bit integer | 0 | 1 |
| I:e.3 | channel 11 data word | 14-bit integer | 0 | 1 |
| I:e.4 | channel 12 data word | 14-bit integer | 0 | 1 |
| I:e.5 | channel 13 data word | 14-bit integer | 0 | 1 |
| I:e.6 | channel 14 data word | 14-bit integer | 0 | 1 |
| I:e.7 | channel 15 data word | 14-bit integer | 0 | 1 |

(1) In Class 1, bit 1 determines whether data or status resides in the input image. Bit 0 determines whether channels 0 through 7 or 8 through 15 are shown.

| Class 3 Data Word | | |
|--------------------------|----------------------|----------------|
| l:e.0 | channel 0 data word | 16-bit integer |
| l:e.1 | channel 1 data word | 16-bit integer |
| l:e.2 | channel 2 data word | 16-bit integer |
| l:e.3 | channel 3 data word | 16-bit integer |
| l:e.4 | channel 4 data word | 16-bit integer |
| l:e.5 | channel 5 data word | 16-bit integer |
| l:e.6 | channel 6 data word | 16-bit integer |
| l:e.7 | channel 7 data word | 16-bit integer |
| l:e.8 | channel 8 data word | 16-bit integer |
| l:e.9 | channel 9 data word | 16-bit integer |
| l:e.10 | channel 10 data word | 16-bit integer |
| l:e.11 | channel 11 data word | 16-bit integer |
| l:e.12 | channel 12 data word | 16-bit integer |
| l:e.13 | channel 13 data word | 16-bit integer |
| l:e.14 | channel 14 data word | 16-bit integer |
| l:e.15 | channel 15 data word | 16-bit integer |

The channel data word contains a 16-bit integer that represents the value of the analog input channel. The tables below show the channel data word values for various input types and data formats. The second table shows the default full-scale values for the proportional counts data format. The table does not imply the entire data value range is usable resolution.

| Channel Data Word Values for Engineering Units | | | |
|---|---------------------|--------------------------|--------------------------------|
| Input Type | Signal Range | Engineering Units | Engineering Units Scale |
| ±10V dc | -10.25V to +10.25V | -10250 to +10250 | 1 mV/step |
| 0 to 5V dc | -0.25V to +5.25V | -250 to +5250 | 1 mV/step |
| 1 to 5V dc | +0.75V to +5.25V | +750 to +5250 | 1 mV/step |
| 0 to 10V dc | -0.5V to +10.25V | -500 to +10250 | 1 mV/step |
| 0 to 20 mA | -1.0 mA to 21 mA | -1000 to +21000 | 1.0 µA/step |
| 4 to 20 mA | 3.0 mA to 21mA | 3000 to 21000 | 1.0 µA/step |
| ±20 mA | -21 mA to 21 mA | -21000 to +21000 | 1.0 µA/step |
| 0 to 1 mA | -0.05 mA to 1.05 mA | -50 to +1050 | 1.0 µA/step |

| Channel Data Word Values for Scaled Data | | | | |
|--|---------------------|----------------|-------------------------------|--------------------------|
| Input Type | Signal Range | Scaled-for-PID | Proportional Counts (default) | NI4 Data Format |
| ±10V dc | -10.00V to +10.00V | 0 to 16383 | -32768 to 32767 | -32768 to 32767 |
| 0 to 5V dc | 0.0V to +5.00V | 0 to 16383 | -32768 to 32767 | 0 to 16384 |
| 1 to 5V dc | +1.00V to +5.00V | 0 to 16383 | -32768 to 32767 | 3277 to 16384 |
| 0 to 10V dc | 0.0V to +10.00 V | 0 to 16383 | -32768 to 32767 | 0 to 32767 |
| 0 to 20 mA | 0.0 mA to 20.0 mA | 0 to 16383 | -32768 to 32767 | 0 to 16384 |
| 4 to 20 mA | 4.0 mA to 20.0 mA | 0 to 16383 | -32768 to 32767 | 3277 to 16384 |
| ±20 mA | -20.0 mA to 20.0 mA | 0 to 16383 | -32768 to 32767 | -16384 to 16384 |
| 0 to 1 mA | 0.0 mA to 1.00 mA | 0 to 16383 | -32768 to 32767 | 0 to 1000 ⁽¹⁾ |

(1) This data format is not supported by the 1746-NI4 module, but is available for the 1746-NI8 and 1746-NI16 modules.

Scaling the Channel Data Word

This section provides descriptions of how the data types are expressed in the channel data word and examples of how to mathematically convert the data.

Data Type Descriptions

The **engineering units** are 1 mV/step for voltage input types and 1.0 µA/step for current input types.

The **scaled-for-PID** value is a 14-bit unsigned integer, with 0 representing the low-scale value and 16,383 representing the full-scale value minus 1 LSB. The input signal range is proportional to your selected input type and scaled into a 0-16,383 range, which is standard to the SLC PID algorithm.

The **proportional count** value is a 16-bit signed integer. The input signal range is proportional to your selected input and scaled into a -32,768 to 32,767 range.

The **1746-NI4 data format** converts the current and voltage signals into 16-bit two's complement binary values. The table below identifies the current and voltage input ranges for the input channels, the number of significant bits, and the resolution.

| Voltage/Current Range | Decimal Representation | Number of Significant Bits | Resolution per LSB |
|---------------------------|------------------------|----------------------------|--------------------------|
| -10V dc to +10V dc - 1LSB | -32768 to +32,767 | 16 bits | 305.176 μ V |
| 0 to 5V dc | 0 to 16,384 | 14 bits | |
| 1 to 5V dc | 3,277 to 16,383 | 13.67 bits | |
| 0 to 10V dc - 1LSB | 0 to 32,767 | 15 bits | |
| 0 to 20 mA | 0 to 16,384 | 14 bits | 1.22070 μ A |
| 4 to 20 mA | 3,277 to 16,384 | 13.67 bits | |
| -20 mA to +20 mA | -16,384 to +16,384 | 15 bits | |
| 0 to 1 mA | 0 to 1000 | 10 bits | 1 μ A ⁽¹⁾ |

(1) This data format is not supported by the 1746-NI4 module, but is available for the 1746-NI8 and 21746-NI16 modules.

User-defined scaling count (Class 3 operation only) allows the output image data words 16 and 17, 18 and 19, 20 and 21, or 22 and 23 to be selected to represent low-scale and high-scale limits. The module uses these limits and scales proportionately between them. For example, if words 16 and 17 are selected to represent low and high scaling ranges, and word 16 contains 0 (decimal), and word 17 contains 20000 (decimal), this would represent the range of values to which the voltage or current readings would be scaled. The lowest voltage or current reading would be scaled to 0, and the highest voltage or current reading would be scaled to 20000, with other readings scaled proportionately between them.

If the module is in Class 1 mode, and you attempt to configure for user-defined proportional counting, a configuration error is generated.

Using Scaled-for-PID and Proportional Counts

The scaled-for-PID and proportional count selections provide the highest display resolution, but also require you to manually convert the channel data to “real” units.

Scaling Examples

The following scaling examples show how to convert the channel data word from the configured data type to “real” units. Real units are the values being measured, such as temperature and pressure. To perform the scaling, you must know the defined voltage or current range for the channel’s input type. The lowest possible actual value for an input type is ScaledMin, and the highest possible actual value is ScaledMax. Refer to the Channel Data Word Value tables on page 5-9 and page 5-10 for the channel word signal ranges.

NOTE

In all of the examples on pages 5-13 to 5-15, the zero offset is the low range limit (InputMin).

Formulas

Three formulas are used in all of the following examples. They are:

$$\text{Scaled Value} = (\text{Input Value} \times \text{Slope}) + \text{Offset}$$

where:

$$\text{Slope} = \frac{(\text{ScaledMax} - \text{ScaledMin})}{(\text{InputMax} - \text{InputMin})}$$

and

$$\text{Offset} = \text{ScaledMin} - (\text{InputMin} \times \text{Slope})$$

Engineering Units to Real Units

Example #1: A transducer is being used to measure temperature.

The 4 to 20 mA signal is proportional to 100 to 500°C (212 to 932°F).
The input data is in engineering units, i.e. 4 to 20 mA
where

$$\frac{4\text{mA}}{1\mu\text{A per step}} = 4000$$

and

$$\frac{20\text{mA}}{1\mu\text{A per step}} = 20000$$

Input value to convert = 5500

The scaled range is 212 to 932°F

The input range is 4000 to 20000

Find: Input Value in °F.

Per the equations above:

$$\text{Slope} = \frac{(932 - 212)}{(20000 - 4000)} = 0.045$$

$$\text{Offset} = 212 - (4000 \times 0.045) = 32$$

$$\text{Scaled Value} = (5500 \times 0.045) + 32 = \mathbf{279.5^\circ\text{F}}$$

Example #2: A transducer is being used to measure temperature.

The 0 to 10V dc signal range is proportional to 0 to 10°C.
The input data is in engineering units, i.e. 0 to 10V dc
where

$$\frac{10\text{Vdc}}{1\text{mV per step}} = 10000$$

Input value to convert = 5000.

Find: Input value in °C.

Per the equations above:

$$\text{Slope} = \frac{(10 - 0)}{(10000 - 0)} = 0.001$$

$$\text{Offset} = 0 - (0 \times 0.001) = 0$$

$$\text{Scaled Value} = 5000 \times 0.001 = \mathbf{5^\circ\text{C}}$$

Scaled-for-PID to Real Units

Example: #3 A transducer is being used to measure temperature.

The 4 to 20 mA signal range is proportional to 100 to 500°C (212 to 932°F)

The input data is scaled for PID, i.e. input range of 0 to 16383

Input value to convert = 5500

The scaled range is 212 to 932°F

The Input range is 0 to 16383

Find: Input value in °F

Per the equation above:

$$\text{Slope} = \frac{(932 - 212)}{(16383 - 0)} = 0.044$$

$$\text{Offset} = 212 - (0 \times 0.044) = 212$$

$$\text{Scaled Value} = (5500 \times 0.044) + 212 = \mathbf{454^\circ\text{F}}$$

Proportional Counts to Real Units

Example: #4 A transducer is being used to measure pressure.

The -10V dc to +10V dc signal range is proportional to 0 to 200 psi

The input data is in "Proportional Counts" data format, i.e. -32768 to 32767

Input value to convert = 21567

The Scaled range is 0 to 200 psi

The Input range is -32768 to 32767

Find: Input value in psi

Per the equation above:

$$\text{Slope} = \frac{(200 - 0)}{[32767 - (-32768)]} = 0.003$$

$$\text{Offset} = 0 - (-32768(0.003)) = 98.3$$

$$\text{Scaled Value} = (21567 \times 0.003) + 98.3 = \mathbf{163\text{ psi}}$$

1746-NI4 Data Format Units to Real Units

Example: #5 A transducer is being used to measure flow rate.

The -10V dc to +10V dc signal range is proportional to 0 to 100 GPM
 The input data is in "1746-NI4" format, i.e. input range of -32768 to 32767
 Input value to convert = 10000

The Scaled range is 0 to 100 GPM
 The Input range is -32768 to +32767

Find: Input value in GPM

Per the equations above:

$$\text{Slope} = \frac{(100 - 0)}{[32767 - (-32768)]} = 0.0015$$

$$\text{Offset} = 0 - (-32768 \times 0.0015) = 49.15$$

$$\text{Scaled Value} = (10000 \times 0.0015) + 49.15 = \mathbf{64.15 \text{ GPM}}$$

User-Defined Scaling Data Format to Real Units

Example: #6 A transducer is being used to measure pressure.

The -10V dc to +10V dc signal range is proportional to 0 to 200 psi
 The input data is in "User Defined Format", where:
 The lower input limit (configuration word 8) = 0
 The upper input limit (configuration word 9) = 20000
 Input value to convert = 16600

Scaled range is 0 to 200 psi
 Input range is 0 to 20000

Find: Input value in psi

Per the equation above:

$$\text{Slope} = \frac{(200 - 0)}{(20000 - 0)} = 0.01$$

$$\text{Offset} = 0 - (0 \times 0.01) = 0$$

$$\text{Scaled Value} = 16600 \times 0.01 = \mathbf{166 \text{ psi}}$$

Channel Status Checking

If the module is in Class 3 mode, there are 8 additional input image words available for status information. The channel status word is a part of the module's input image. Input words 16 to 31 correspond to and contain the configuration status of channels 0 to 15. You can use the data provided in the status word to determine if the input configuration data for any channel is valid per your configuration in O:e.0 through O:e.15.

For example, whenever a channel is disabled (O:e.x/15 = 0), its corresponding status word shows all zeros. This condition tells you that input data contained in the data word for that channel is not valid and should be ignored.

| Class 1 Status Word | | | Bit 1 set to ⁽¹⁾ | Bit 0 set to ⁽¹⁾ |
|---------------------|------------------------|------------------|-----------------------------|-----------------------------|
| I:e.0 | channel 0 status word | bit-mapped field | 1 | 0 |
| I:e.1 | channel 1 status word | bit-mapped field | 1 | 0 |
| I:e.2 | channel 2 status word | bit-mapped field | 1 | 0 |
| I:e.3 | channel 3 status word | bit-mapped field | 1 | 0 |
| I:e.4 | channel 4 status word | bit-mapped field | 1 | 0 |
| I:e.5 | channel 5 status word | bit-mapped field | 1 | 0 |
| I:e.6 | channel 6 status word | bit-mapped field | 1 | 0 |
| I:e.7 | channel 7 status word | bit-mapped field | 1 | 0 |
| I:e.0 | channel 8 status word | bit-mapped field | 1 | 1 |
| I:e.1 | channel 9 status word | bit-mapped field | 1 | 1 |
| I:e.2 | channel 10 status word | bit-mapped field | 1 | 1 |
| I:e.3 | channel 11 status word | bit-mapped field | 1 | 1 |
| I:e.4 | channel 12 status word | bit-mapped field | 1 | 1 |
| I:e.5 | channel 13 status word | bit-mapped field | 1 | 1 |
| I:e.6 | channel 14 status word | bit-mapped field | 1 | 1 |
| I:e.7 | channel 15 status word | bit-mapped field | 1 | 1 |

(1) In Class 1, bit 1 determines whether data or status resides in the input image. Bit 0 determines whether channels 0 through 7 or 8 through 15 are shown.

| Class 3 Status Word | | |
|----------------------------|------------------------|------------------|
| l:e.16 | channel 0 status word | bit-mapped field |
| l:e.17 | channel 1 status word | bit-mapped field |
| l:e.18 | channel 2 status word | bit-mapped field |
| l:e.19 | channel 3 status word | bit-mapped field |
| l:e.20 | channel 4 status word | bit-mapped field |
| l:e.21 | channel 5 status word | bit-mapped field |
| l:e.22 | channel 6 status word | bit-mapped field |
| l:e.23 | channel 7 status word | bit-mapped field |
| l:e.24 | channel 8 status word | bit-mapped field |
| l:e.25 | channel 9 status word | bit-mapped field |
| l:e.26 | channel 10 status word | bit-mapped field |
| l:e.27 | channel 11 status word | bit-mapped field |
| l:e.28 | channel 12 status word | bit-mapped field |
| l:e.29 | channel 13 status word | bit-mapped field |
| l:e.30 | channel 14 status word | bit-mapped field |
| l:e.31 | channel 15 status word | bit-mapped field |

The channel status word can be analyzed bit by bit. In addition to providing information about an enabled or disabled channel, each bit's status (0 or 1) tells you how the input data from the voltage or current analog sensor connected to a specific channel is translated for your application. The bit status also informs you of any error condition and can tell you what type of error occurred.

A bit-by-bit examination of the status word for Class 1 and Class 3 is provided in the respective charts on the following pages.

Class 1 Status Word

| Define | To Select | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--|---|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| Class 1 Data or Status Configuration | Data from Channel 0 to 7 | | | | | | | | | | | | | | | 0 | 0 |
| | Data from Channel 8 to 15 | | | | | | | | | | | | | | | 0 | 1 |
| | Status for Channel 0 to 7 | | | | | | | | | | | | | | | 1 | 0 |
| | Status for Channel 8 to 15 | | | | | | | | | | | | | | | 1 | 1 |
| Input Type | ±10 Vdc or ± 20 mA | | | | | | | | | | | | | | 0 | 0 | |
| | 1 to 5 Vdc or 4 to 20 mA | | | | | | | | | | | | | | 0 | 1 | |
| | 0 to 5 Vdc or 0 to 1 mA | | | | | | | | | | | | | | 1 | 0 | |
| | 0 to 10 Vdc or 0 to 20 mA | | | | | | | | | | | | | | 1 | 1 | |
| Data Format | Engineering Units | | | | | | | | | | | 0 | 0 | | | | |
| | Scaled-for-PID | | | | | | | | | | | 0 | 1 | | | | |
| | Proportional Counts | | | | | | | | | | | 1 | 0 | | | | |
| | 1746-NI4 Data Format | | | | | | | | | | | 1 | 1 | | | | |
| Class 1 Handshaking | Ready to receive channel configuration | | | | | | | | | | 0 | | | | | | |
| | Processed channel configuration | | | | | | | | | | 1 | | | | | | |
| Calibrate Channel Status | Normal RUN Mode (Exit Calibration Mode) | | | | | | | 0 | 0 | 0 | | | | | | | |
| | Calibration Mode Entered | | | | | | | 0 | 0 | 1 | | | | | | | |
| | Zero Value Calibrated | | | | | | | 0 | 1 | 1 | | | | | | | |
| | Full Scale Calibrated | | | | | | | 1 | 0 | 1 | | | | | | | |
| Filter Frequency Filter frequencies are set in ch 0, 4, 8 and 12 for that channel and the following 3 channels in that group. Filter groupings are: (0 to 3) (4 to 7) (8 to 11) and (12 to 15) | 6 Hz | | | | 0 | 0 | 0 | | | | | | | | | | |
| | 10 Hz | | | | 0 | 0 | 1 | | | | | | | | | | |
| | 20 Hz | | | | 0 | 1 | 0 | | | | | | | | | | |
| | 40 Hz | | | | 0 | 1 | 1 | | | | | | | | | | |
| | 60 Hz | | | | 1 | 0 | 0 | | | | | | | | | | |
| | 80 Hz | | | | 1 | 0 | 1 | | | | | | | | | | |
| | 100 Hz | | | | 1 | 1 | 0 | | | | | | | | | | |
| | 250 Hz | | | | 1 | 1 | 1 | | | | | | | | | | |
| Error Conditions | Channel Disabled | 0 | 0 | 0 | | | | | | | | | | | | | |
| | Faulty Calibration | 0 | 0 | 1 | | | | | | | | | | | | | |
| | Invalid Calibration Reference | 0 | 1 | 0 | | | | | | | | | | | | | |
| | Configuration Error | 0 | 1 | 1 | | | | | | | | | | | | | |
| | Open-Circuit Detected | 1 | 0 | 0 | | | | | | | | | | | | | |
| | Under-Range Detected | 1 | 0 | 1 | | | | | | | | | | | | | |
| | Over-Range Detected | 1 | 1 | 0 | | | | | | | | | | | | | |
| | No Error | 1 | 1 | 1 | | | | | | | | | | | | | |

NOTE

Bits 1 and 0 indicate origin in Class 1 mode. Bits 15 through 2 contain real data for each channel.

If the module is in Class 3 mode, all 16 bits are real data (depending on the data type).

Class 3 Status Word

| Define | To Select | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--|---|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| Class 1 Data or Status Configuration | Data from Channel 0 to 7 | | | | | | | | | | | | | | | 0 | 0 |
| | Data from Channel 8 to 15 | | | | | | | | | | | | | | | 0 | 1 |
| | Status for Channel 0 to 7 | | | | | | | | | | | | | | | 1 | 0 |
| | Status for Channel 8 to 15 | | | | | | | | | | | | | | | 1 | 1 |
| Input Type | ± 10 Vdc or ± 20 mA | | | | | | | | | | | | | | 0 | 0 | |
| | 1 to 5 Vdc or 4 to 20 mA | | | | | | | | | | | | | | 0 | 1 | |
| | 0 to 5 Vdc or 0 to 1 mA | | | | | | | | | | | | | | 1 | 0 | |
| | 0 to 10 Vdc or 0 to 20 mA | | | | | | | | | | | | | | 1 | 1 | |
| Data Format | Engineering Units | | | | | | | | | | 0 | 0 | 0 | | | | |
| | Scaled-for-PID | | | | | | | | | | 0 | 0 | 1 | | | | |
| | Proportional Counts | | | | | | | | | | 0 | 1 | 0 | | | | |
| | 1746-NI4 Data Format | | | | | | | | | | 0 | 1 | 1 | | | | |
| | User Limit Range 0 | | | | | | | | | | 1 | 0 | 0 | | | | |
| | User Limit Range 1 | | | | | | | | | | 1 | 0 | 1 | | | | |
| | User Limit Range 2 | | | | | | | | | | 1 | 1 | 0 | | | | |
| | User Limit Range 3 | | | | | | | | | | 1 | 1 | 1 | | | | |
| Calibrate Channel Status | Normal RUN Mode (Exit Calibration Mode) | | | | | | | 0 | 0 | 0 | | | | | | | |
| | Calibration Mode Entered | | | | | | | 0 | 0 | 1 | | | | | | | |
| | Zero Value Calibrated | | | | | | | 0 | 1 | 1 | | | | | | | |
| | Full Scale Calibrated | | | | | | | 1 | 0 | 1 | | | | | | | |
| Filter Frequency Filter frequencies are set in ch 0, 4, 8 and 12 for that channel and the following 3 channels in that group. Filter groupings are: (0 to 3) (4 to 7) (8 to 11) and (12 to 15) | 6 Hz | | | | 0 | 0 | 0 | | | | | | | | | | |
| | 10 Hz | | | | 0 | 0 | 1 | | | | | | | | | | |
| | 20 Hz | | | | 0 | 1 | 0 | | | | | | | | | | |
| | 40 Hz | | | | 0 | 1 | 1 | | | | | | | | | | |
| | 60 Hz | | | | 1 | 0 | 0 | | | | | | | | | | |
| | 80 Hz | | | | 1 | 0 | 1 | | | | | | | | | | |
| | 100 Hz | | | | 1 | 1 | 0 | | | | | | | | | | |
| | 250 Hz | | | | 1 | 1 | 1 | | | | | | | | | | |
| Error Conditions | Channel Disabled | 0 | 0 | 0 | | | | | | | | | | | | | |
| | Faulty Calibration | 0 | 0 | 1 | | | | | | | | | | | | | |
| | Invalid Calibration Reference | 0 | 1 | 0 | | | | | | | | | | | | | |
| | Configuration Error | 0 | 1 | 1 | | | | | | | | | | | | | |
| | Open-Circuit Detected | 1 | 0 | 0 | | | | | | | | | | | | | |
| | Under-Range Detected | 1 | 0 | 1 | | | | | | | | | | | | | |
| | Over-Range Detected | 1 | 1 | 0 | | | | | | | | | | | | | |
| | No Error | 1 | 1 | 1 | | | | | | | | | | | | | |

NOTE

Bits 1 and 0 indicate origin in Class 1 mode. Bits 15 through 2 contain real data for each channel.

If the module is in Class 3 mode, all 16 bits are real data, depending on the data type.

NOTE

If the channel whose status you are checking is disabled (bit O:e.x/15 = 0), all bit fields are cleared. The status word for any disabled channel is always 0000 0000 0000 0000 regardless of any previous setting that may have been made to the configuration word in Class 3.

Input Word Bit Definitions **Error Conditions (Bits 15 through 13)**

There are eight possible error codes to describe any given state of the 1746-NI16 module. The following table shows the different error codes and their associated bit settings. For more information on the error codes, see “Error Codes” on page 6-5.

| Error Condition | Bit 15 | Bit 14 | Bit 13 |
|-------------------------------|---------------|---------------|---------------|
| Channel Disabled | 0 | 0 | 0 |
| Faulty Calibration | 0 | 0 | 1 |
| Invalid Calibration Reference | 0 | 1 | 0 |
| Configuration Error | 0 | 1 | 1 |
| Open-Circuit Detected | 1 | 0 | 0 |
| Under-Range Detected | 1 | 0 | 1 |
| Over-Range Detected | 1 | 1 | 0 |
| No Error | 1 | 1 | 1 |

Filter Frequency (Bits 12 through 10)

The channel filter frequency bits reflects the filter frequency selected in the configuration word. Filter frequencies are active for all current and voltage input types. The filter frequency bits are cleared while the channel is disabled.

Calibrate Channel Status (Bits 9 through 7)

The calibrate channel status bits indicate the completion of the calibration process. The code of (0 0 0) indicates that the channel is in the normal run mode or this code can be used to exit the calibration mode. If bit 7 is set to 1, the channel is in the calibration mode. If bit 8 is set to 1, the channel has successfully calibrated the zero reference point. If bit 9 is set to 1, the channel has successfully calibrated the full-scale reference point.

For more information on the calibration procedure, see Appendix D.

Class 1 Handshaking (Bit 6)

Bit 6 is only necessary when in Class 1 mode. Class 3 does not need bit 6 for configuration. While in Class 1, bit 6 is 0, signifying that the channel is ready to receive configuration information. After processing configuration information for that channel bit 6 is set to 1. Bit 6 must be cleared (0) to complete the handshaking cycle.

Class 3 Data Format (Bits 6 through 4)

The data format bit field indicates the data format defined for the channel. This field reflects the data format selected in the channel configuration word. The data format field is cleared when the channel is disabled. In Class 3, an extra bit (bit 6) is allotted to indicate which user limit range (0, 1, 2 or 3) was selected.

Class 1 Data Format (Bits 5 and 4)

The data format bit field indicates the data format defined for the channel. This field reflects the data format selected in the channel configuration word. The data format field is cleared when the channel is disabled. In Class 1, only 2 bits describe the data format because user limits ranges are not selectable in Class 1.

Input Type (Bits 3 and 2)

The input type bit field indicates what type of input signal the channel is configured for, based on the configuration word. The input type field is cleared when the channel is disabled.

Class 1 Data or Status Configuration (Bits 1 and 0)

When bits 1 and 0 are set to (0 0) or (0 1) in the configuration word, data is being requested from channels 0 to 7 or 8 to 15 in Class 1 to be reflected in the 8 input words. The module returns a 16-bit value for the channel data which can be used directly. However, the resolution of data in Class 1 is only 14 bits. Bits (1 and 0) are overwritten with the data or status configuration information. Therefore, Class 1 operation reports a 16-bit data value with an error within ± 3 LSB of the actual value.

In Class 3, the input word reports 16 words of data and 16 words of status information. When data is being reported in Class 3, the data value is a 16-bit integer, whereby all 16 bits are real data, depending on the data type.

Module Diagnostics and Troubleshooting

This chapter describes troubleshooting using the channel status LEDs as well as the module status LED. It explains the types of conditions that might cause an error to be reported and gives suggestions on how to resolve the problem. Major topics include:

- module operation vs. channel operation
- power-up diagnostics
- channel diagnostics
- LED indicators
- channel status error codes
- troubleshooting flowchart
- replacement parts
- contacting Allen-Bradley

Module operation vs. Channel Operation

The module performs operations at two levels:

- module-level operations
- channel-level operations

Module-level operations include functions such as power-up configuration and communication with the SLC 500 processor.

Channel-level operations describe channel-related functions, such as data conversion and open-circuit detection.

Internal diagnostics are performed at both levels of operation, and any error conditions detected are immediately indicated by the module's LEDs.

Power-Up Diagnostics

At module power-up, a series of internal diagnostic tests are performed. These diagnostic tests must be completed successfully or a module error results and the module status LED remains off.

Channel Diagnostics

When a channel is enabled (bit 15=1), a diagnostic check is performed to see that the channel has been properly configured. In addition, the channel is tested on every scan for configuration errors, out-of-range errors, and, for the 4 to 20 mA input type, open-circuit conditions.

A failure of any channel diagnostic test causes the faulted channel status LED to blink. All channel faults are indicated in bits 15 through 13 of the channel's status word. Channel faults are self-clearing. When the fault conditions are corrected, the channel status LED stops blinking and resume steady illumination.

ATTENTION

If you clear (0) a channel enable bit (15), all channel status information is reset.

Invalid Channel Configuration

Whenever a channel's configuration word is improperly defined, the channel status LED blinks and the channel status word indicated the type of configuration error in bits 15 through 13. See "Error Codes" on page 6-5.

Configuration errors occur when the data format (bits 8 through 6) in the channel configuration word are invalid.

Out-Of-Range Detection

Whenever the data received at the channel data word is out of the defined operating range, an over-range or under-range error is indicated in the channel status word. See "Error Codes" on page 6-5.

Open-Circuit Detection

An open-circuit test is performed on all enabled channels configured for 4 to 20 mA input and all enabled channels with voltage configurations. Whenever an open-circuit condition occurs, the channel status LED blinks and the condition is reported in bits 15 through 13 of the channel status word. See “Error Codes” on page 6-5.

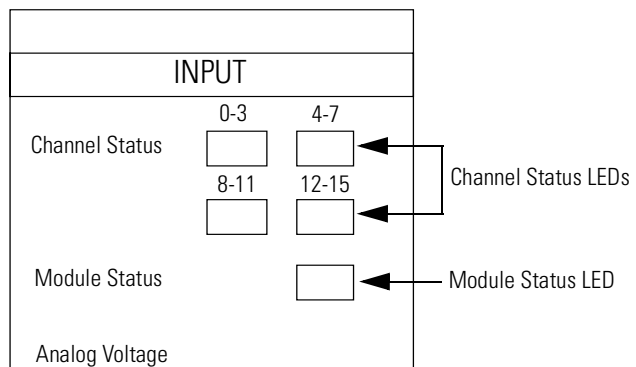
Possible causes of an open-circuit include:

- The sensing device may be broken.
- A wire may be loose or cut.
- The sensing device may not have been installed on the configured channel.

If an open circuit is detected, the channel data word reflects input data as 0 mA in the 4 to 20 mA configuration. For the voltage module, open-circuit data is displayed for all voltage ranges as the maximum value readable in that voltage range. See tables on pages 5-9 and 5-10.

LED Indicators

The module has five LEDs. Four of these are channel status LEDs numbered to correspond to each of the four groups of four input channels (0 to 3, 4 to 7, 8 to 11, 12 to 15). The fifth is a module status LED.



LED State Tables

Module Status LED

| If Module Status LED is: | Indicated condition: | Corrective action: |
|--------------------------|----------------------|--|
| On | Proper Operation | No action required. |
| Off | Module Fault | Cycle power. If condition persists, call your local distributor or Allen-Bradley for assistance. |

All LEDs

| If Module Status LED is: | And Channel Status LED is: | Indicated Condition: | Corrective action: |
|--------------------------|----------------------------|---|--|
| On | On | Channel Enabled | No action required. |
| | Blinking | Open-Circuit Condition | To determine the exact error, check the error bits in the input image bits (15 through 13). Check the channel configuration word for valid data. Make sure that the data format is indicated correctly in status bits. Class 1 data format status bits are bits 5 and 4. Class 3 data format status bits are bits 6-4. See the "Troubleshooting Flowchart" on page 6-6 and Chapter 5 for more information. |
| | | Out-of-Range Condition | |
| | | Channel Configuration Error | |
| | Off | Power-Up | No action required. |
| Channel Not Enabled | | No action required. For an example showing how to enable a channel, see Chapter 2, <i>Quick Start</i> , or Chapter 7, <i>Application Examples</i> . | |

Module Status LED (Green)

The module status LED is used to indicate module-related diagnostic or operating errors. These **non-recoverable errors** may be detected at power-up or during module operation. Once in a module error state, the 1746-NI16 module no longer communicates with the SLC processor. Channel states are disabled, and data words are cleared.

Failure of any diagnostic test results in a non-recoverable error and requires the assistance of your local distributor or Allen-Bradley.

Channel Status LEDs (Green)

The channel status LED is used to indicate channel status and related error information contained in the channel status word. A solid green channel status LED indicates **normal operation**. The channel status LED blinks to indicate **error conditions** such as:

- channel-related configuration errors
- open-circuit errors
- out-of-range errors

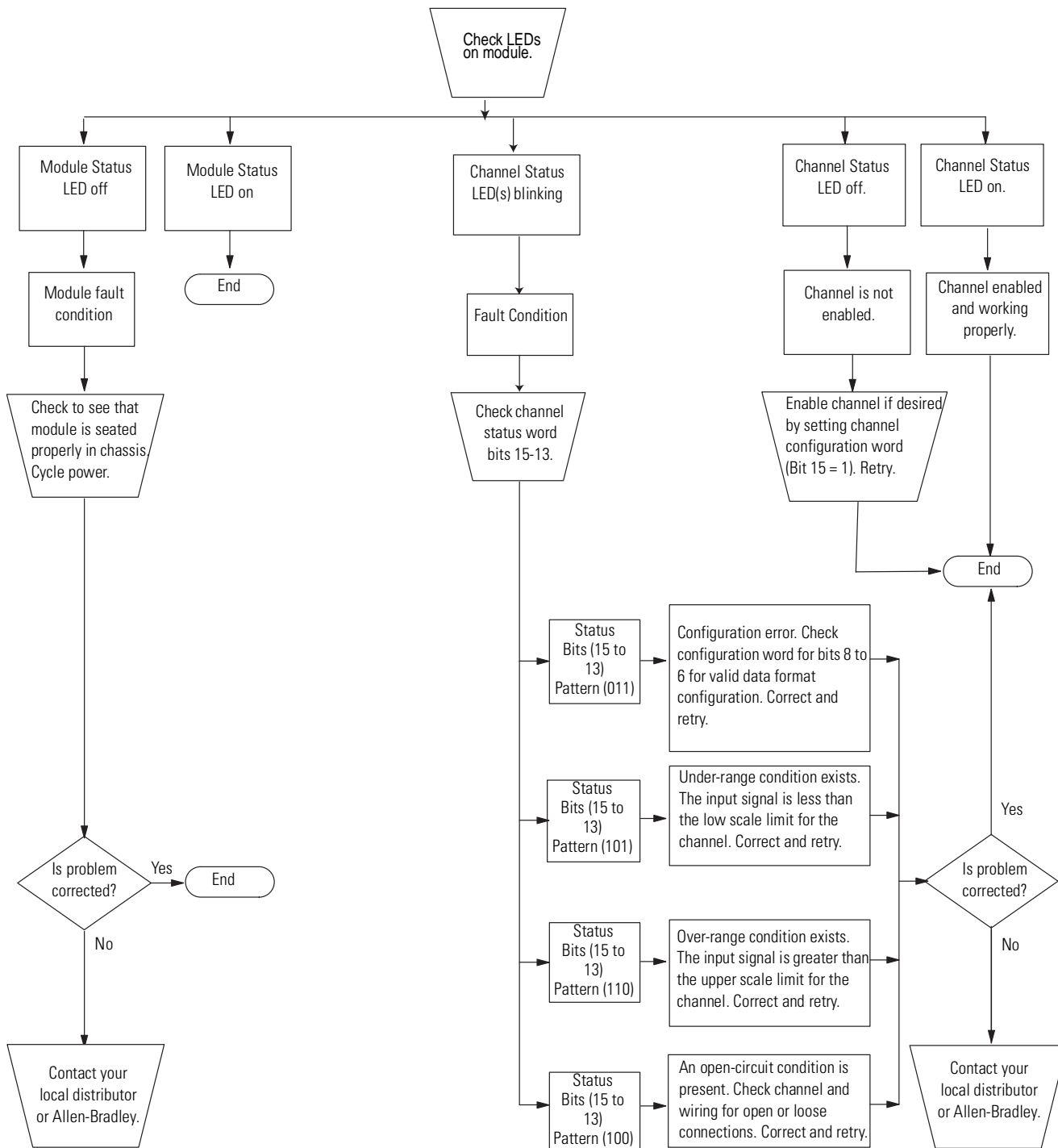
All channel errors are recoverable errors and after corrective action, normal operation resumes.

Error Codes

Bits 15 through 13 of the channel status word indicate error conditions as described in the table below.

| Error Condition | Description | Bit 15 | Bit 14 | Bit 13 |
|--------------------------------------|---|--------|--------|--------|
| Channel Disabled | The channel is disabled. | 0 | 0 | 0 |
| Faulty Calibration | The calibration process was not executed properly. The correct sequence is: (1) the calibration mode must be entered; (2) zero values must be calibrated; and (3) full-scale values are calibrated. See Appendix D for more detailed information on the calibration procedure. | 0 | 0 | 1 |
| Invalid Calibration Reference | A value outside the expected calibration range was applied to the channel for either the zero or full-scale calibration range. See Appendix D for more information on calibration value ranges. | 0 | 1 | 0 |
| Configuration Error | An illegal bit pattern was entered in the configuration word (bits 8 through 6). The configuration error bits are cleared when the channel is disabled. | 0 | 1 | 1 |
| Open-Circuit Detected | The channel has detected an open circuit at its input. The open-circuit state always takes precedence over the out-of-range error states. There will never be an out-of-range error when an open circuit is detected. The open-circuit error bits are cleared when the channel is disabled or when the open-circuit condition is removed. | 1 | 0 | 0 |
| Under-Range Detected | The configured channel has detected an under-range of the data on an input channel. The channel data value is set to the lowest defined value for an under-range condition, based on the selected input type's signal range. The under-range bits are cleared when the channel is disabled. | 1 | 0 | 1 |
| Over-Range Detected | The configured channel has detected an over-range of the data on an input channel. The channel data value is set to the highest defined value for an over-range condition, based on the selected input type's signal range. The over-range bits are cleared when the channel is disabled. | 1 | 1 | 0 |
| No Error | The channel is operating without any errors. | 1 | 1 | 1 |

Troubleshooting Flowchart



Replacement parts

The 1746-NI16 module has the following replacement parts:

| Part | Part Number |
|----------------------------|--------------------|
| Replacement Terminal Block | 1746-RT25G |
| Replacement Terminal Cover | 1746-R13 |
| 1746-NI16 User Manual | 1746-UM001A-US-P |

Contacting Allen-Bradley

If you need to contact Allen-Bradley for assistance, please have the following information available when you call:

- a clear statement of the problem including a description of what the system is actually doing. Note and record the LED states; also, note input and output image words for the module.
- a list of things you have already tried to remedy the problem.
- processor type and firmware (FRN) number. See label on left side of processor.
- hardware types in the system including I/O modules and chassis.
- fault code if the SLC processor is faulted.

Application Examples

Operating Classes

This chapter provides two application examples to help you use the analog input module. They are defined as a:

- Class 1 example
- Class 3 example

Class 1

The Class 1 example shows how to configure, read status, and read data from the NI16 module. Class 1 mode provides 8 words of input image and 8 words of output image for communicating with the NI16 module. Therefore, this example shows how to multiplex 16 words of configuration data to the module with 8 output image words by utilizing a handshaking scheme. Conversely, it also shows how to read analog data from 16 channels with 8 input image words.

Class 3

The Class 3 example shows how to configure, monitor status, and read data from the NI16 module. Class 3 mode provides 32 words of input image and 32 words of output image, making this mode of operation more desirable. The status for all 16 channels can also be monitored constantly, while reading data from all 16 channels.

Class 1 Example

The following ladder logic program configures all 16 channels of the 1746-NI16 module in Class 1 mode. It then instructs the analog input module to begin reading data. Class 1 mode should only be used when the controller is a SLC 500 fixed, SLC-5/01, or when the module is located in a remote I/O chassis with a 1747-ASB. The significance of Class 1 mode is that only 8 input words and 8 output words of image are allowed for exchanging data between the SLC controller and the NI16 module. This means that configuration data, status, and actual analog data for the 16 analog channels must be multiplexed using the 8 I/O image words.

In contrast, Class 3 mode supports up to 32 I/O image words. Class 3 mode can be utilized with SLC 5/02, 5/03, 5/04, 5/05 and also in a remote ControlNet chassis (1747-ACN, ACNR). No multiplexing of data is required, making configuration and reading of status and analog data more straightforward.

The following ladder program enters subroutine File 3 at power-up. File 3 contains logic to configure all 16 analog channels as well as receive and store the 16 status words for each channel. The status words contain success/failure error codes as well as reflecting back the same configuration information contained in the configuration words for each channel. These status words for 16 analog channels are stored in data table words N7:66 through N7:81 and are bit-mapped. Therefore, to understand them, they must be viewed in the Binary Radix. Refer to Chapter 5 for an explanation of each bit in these words.

File 3 configures analog channels 0 to 7, then as each of these channel configurations complete, it configures analog channels 8 to 15. When all 16 channels are configured, subroutine File 3 is no longer scanned. Rungs 2:2 and 2:3 are then alternately enabled to first read the analog data from channels 0 to 7, then from channels 8 to 15.

The program continues to alternate between reading analog data from the first 8 channels, then the last 8 channels, and then storing the data in 16 consecutive words beginning with N7:50. The 16 analog words from N7:50 through N7:65 are in decimal and for this 0 to 10V dc example are represented by the decimal range 0 to 32767. The reason for the fairly complex ladder logic to configure, read status and then read analog data from the NI16 module in Class 1 mode is due to the need to multiplex 16 channels with 8 I/O words.

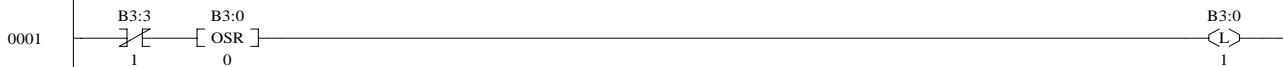
Ladder Files

File 2

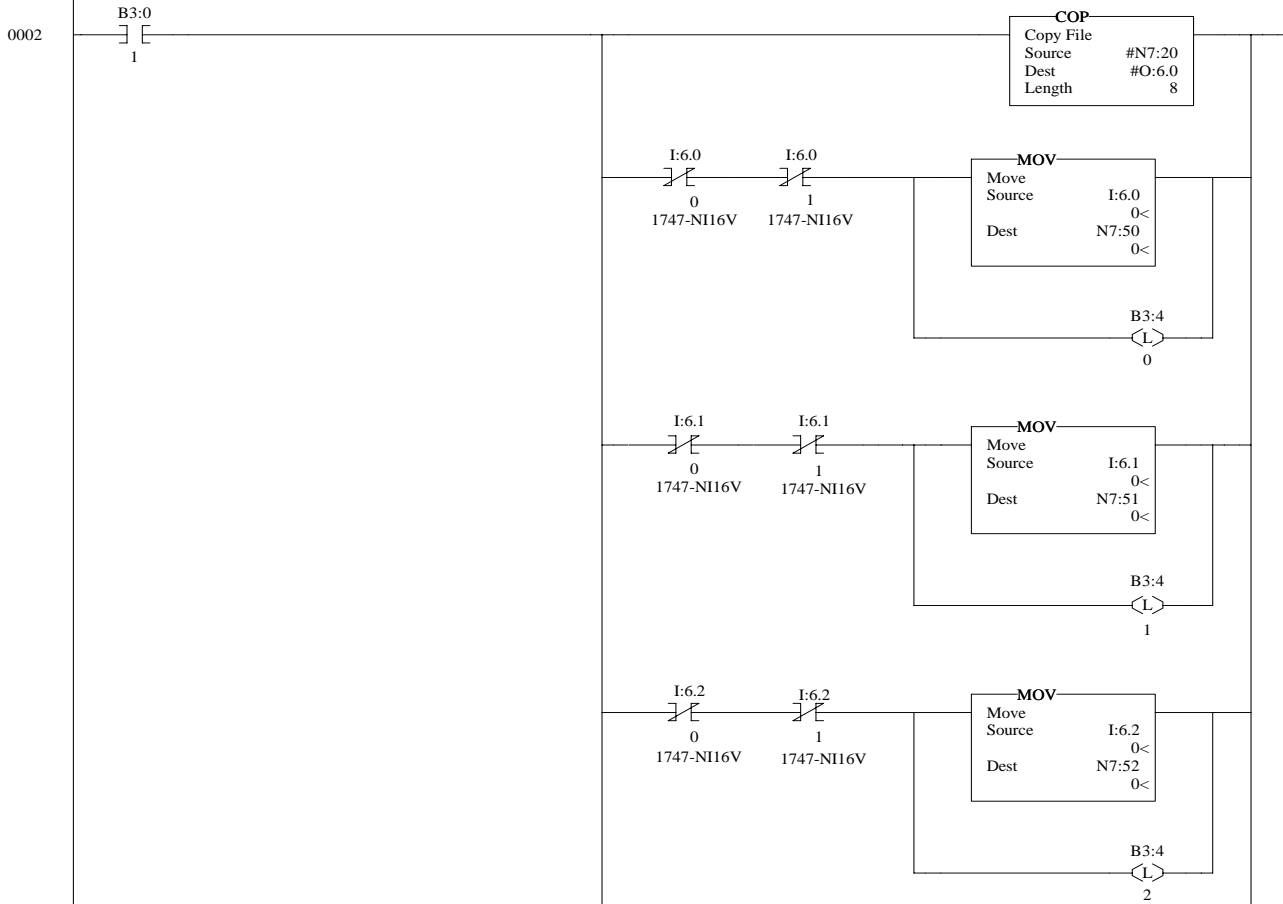
Subroutine file 3 is used to configure all 16 channels of the 1746-NI16. This rung allows subroutine 3 to be scanned until all 16 channels are configured. The status words for all 16 channels containing the results of the configuration will be placed consecutively beginning with N7:66.



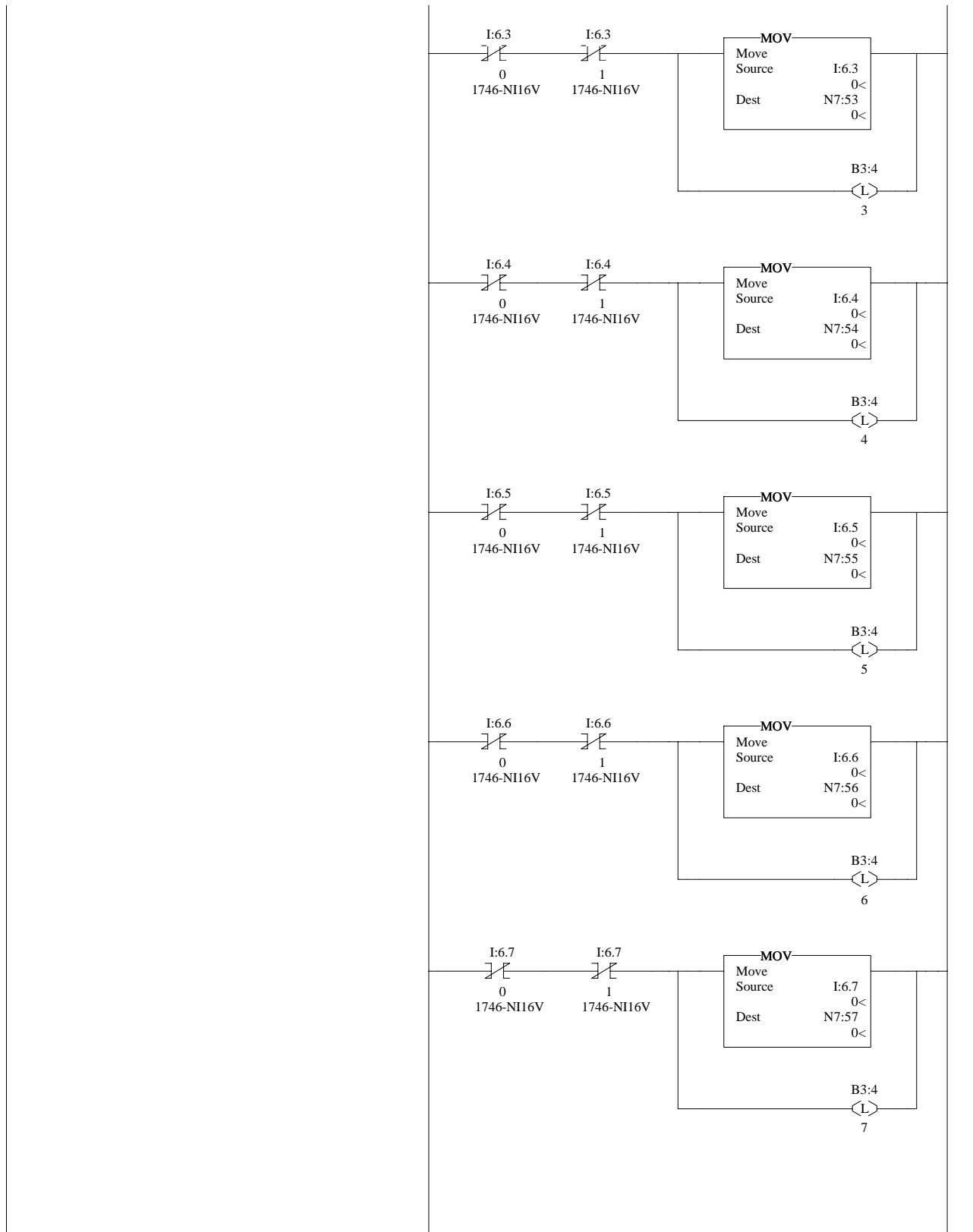
Once the 16 analog channels are configured, B3/1 is latched to instruct the NI16 module to begin sending analog data to the processor for the first 8 channels. B3/2 is used in the next rung to instruct the module to send data from the last 8 channels. Since there are only 8 input image words in Class 1 mode for receiving data from the 16 channel module, this program toggles between the first and last 8 channels and places the data for all 16 channels consecutively beginning with N7:50.



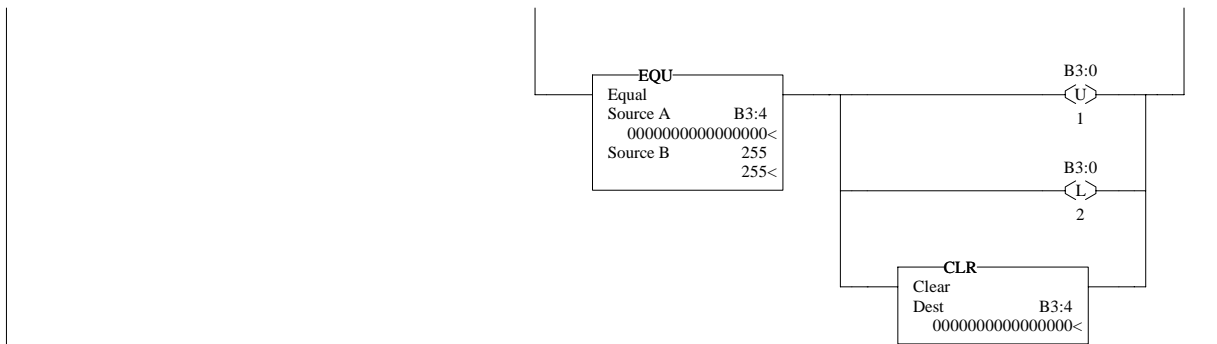
The COP Instruction copies Control Words for channels 0 to 7, requesting analog data for those channels. The data is received from the NI16 in input image words I:6.0 through I:6.7, when bits 0 and 1 for each of these input words are both reset. When all 8 inputs are updated, B3/1 is reset and B3/2 is set to read the data for channels 8 to 15.



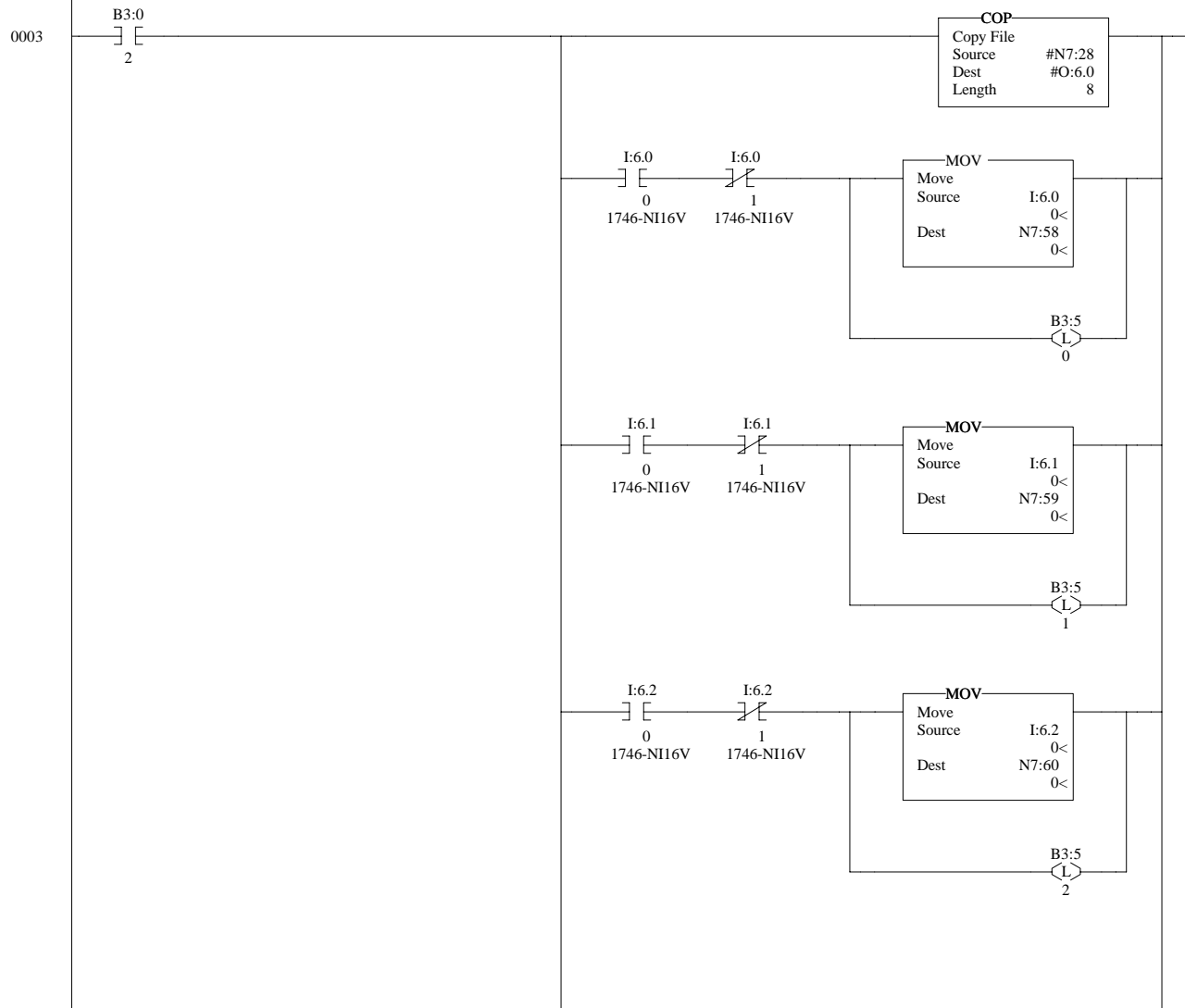
File 2 (Continued)



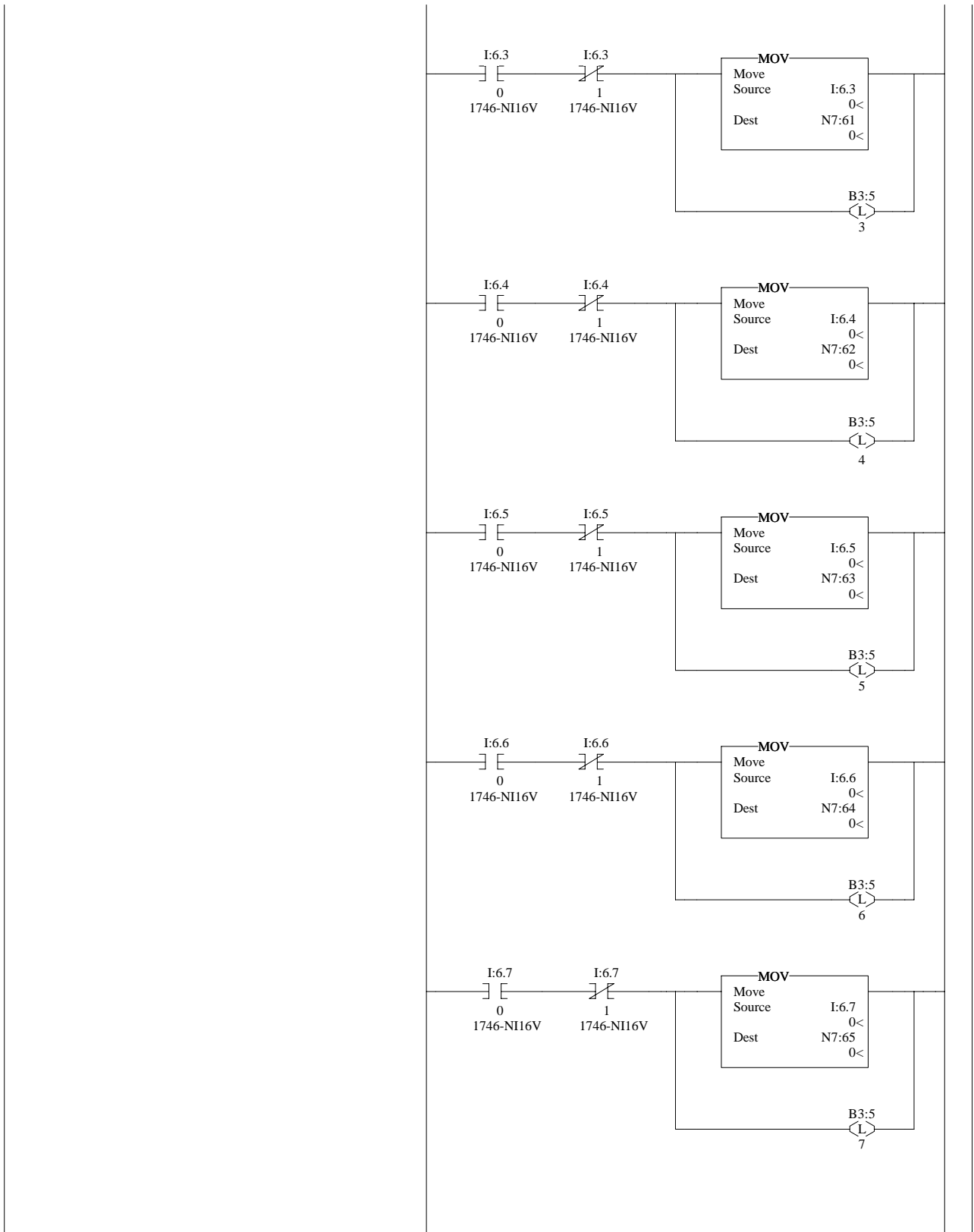
File 2 (Continued)



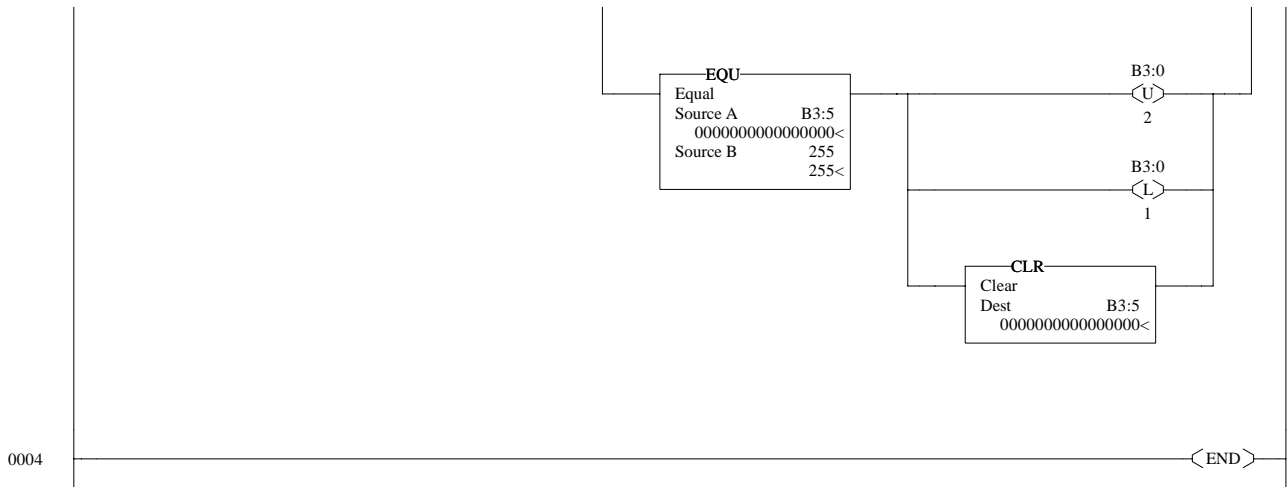
The COP Instruction copies Control Words for channels 8 to 15, requesting analog data for those channels. The data is received from the NI16 in input image words I:6.0 through I:6.7, when bit 0 is set and bit 1 is reset for each of these input words. When all 8 inputs have been updated, B3/2 is reset and B3/1 is set to read the data for channels 0 to 7.



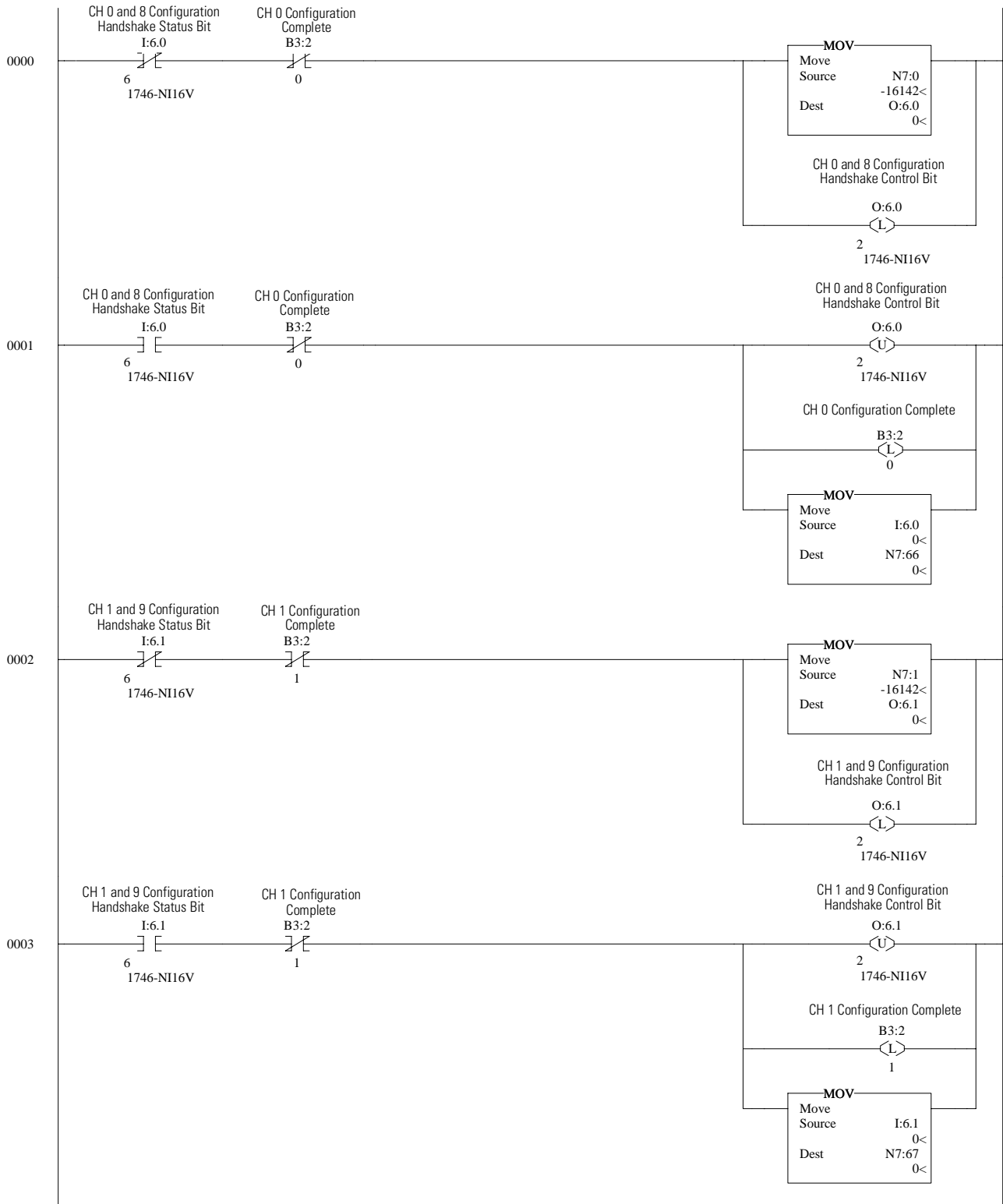
File 2 (Continued)



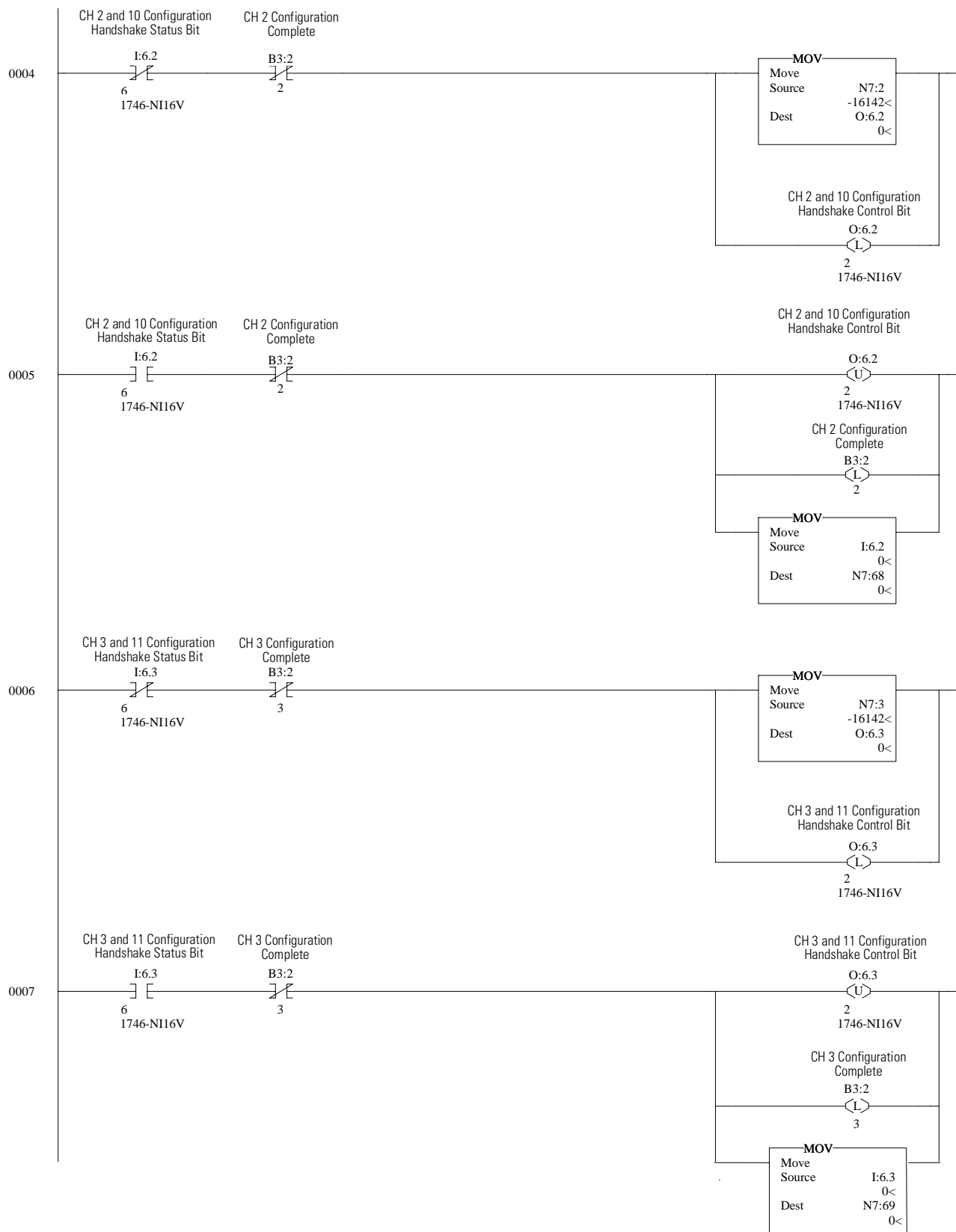
File 2 (Continued)



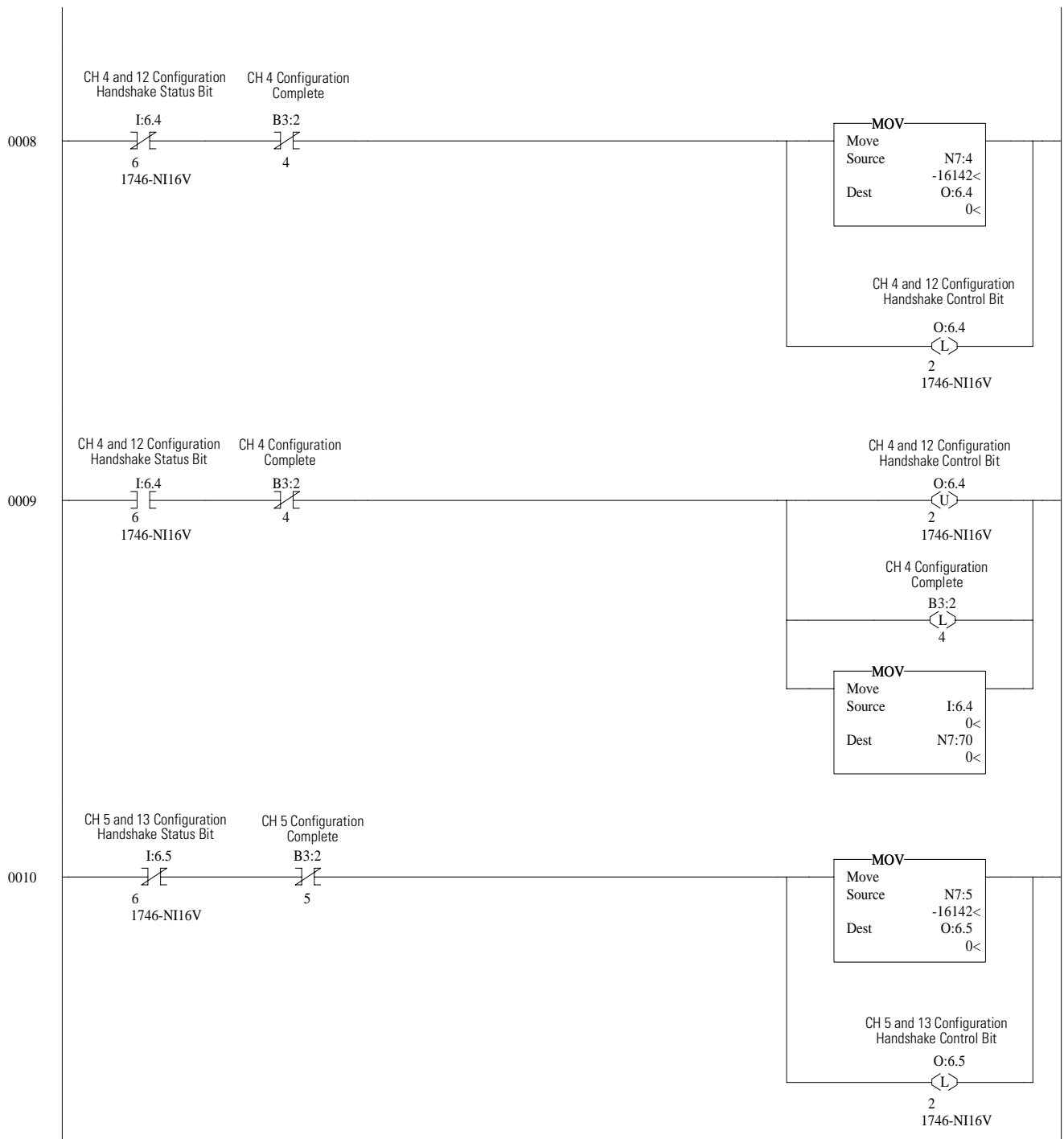
File 3



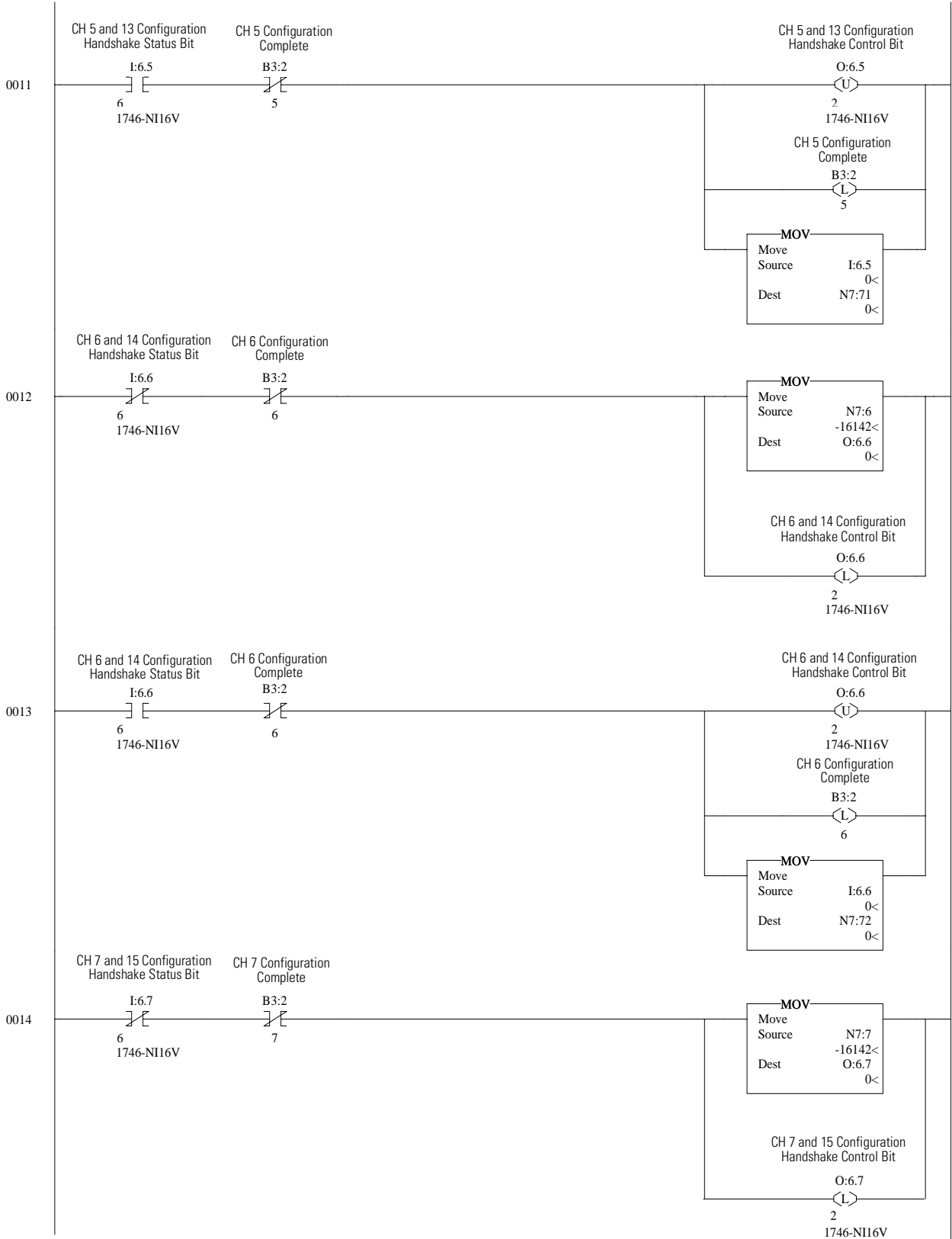
File 3 (Continued)



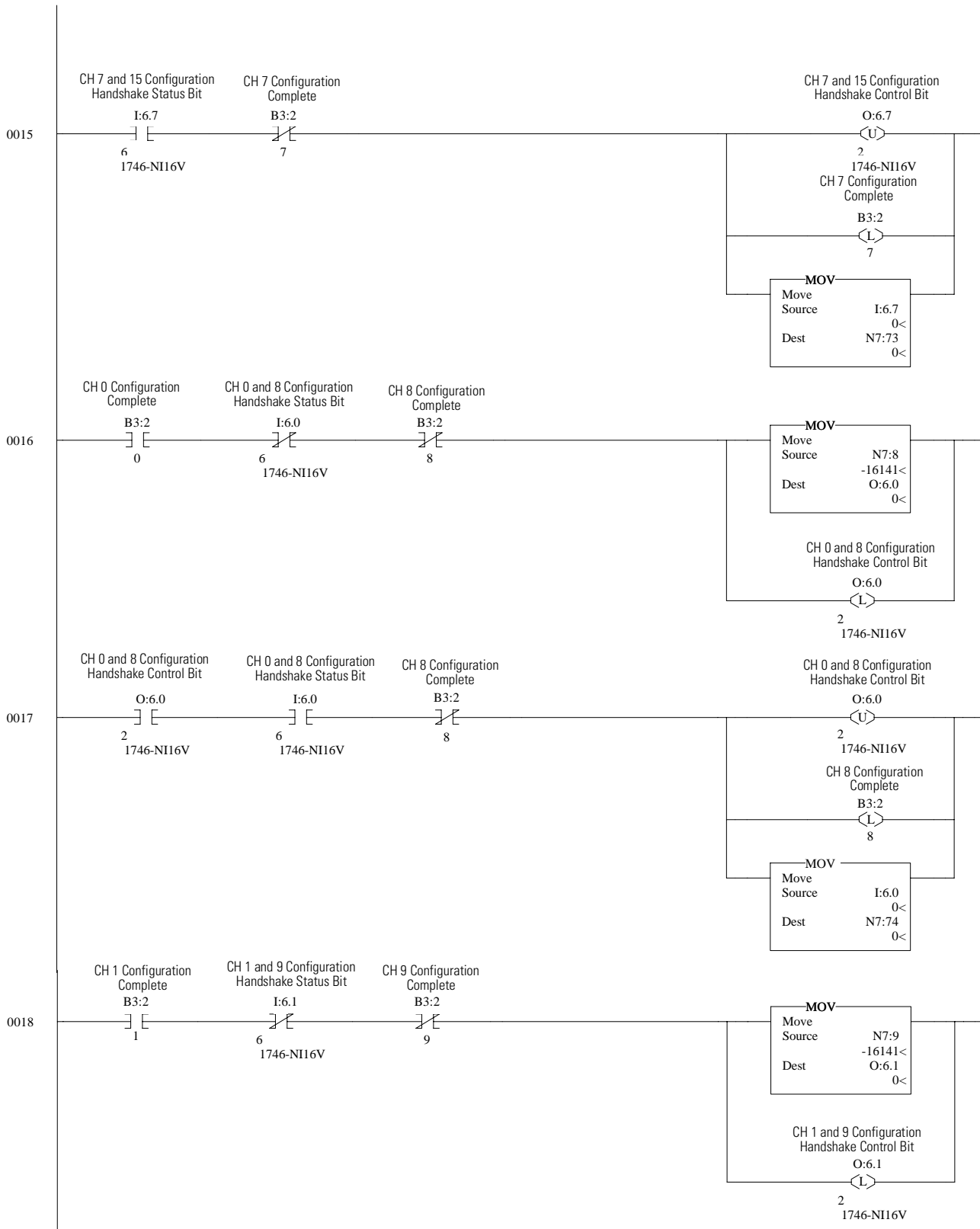
File 3 (Continued)



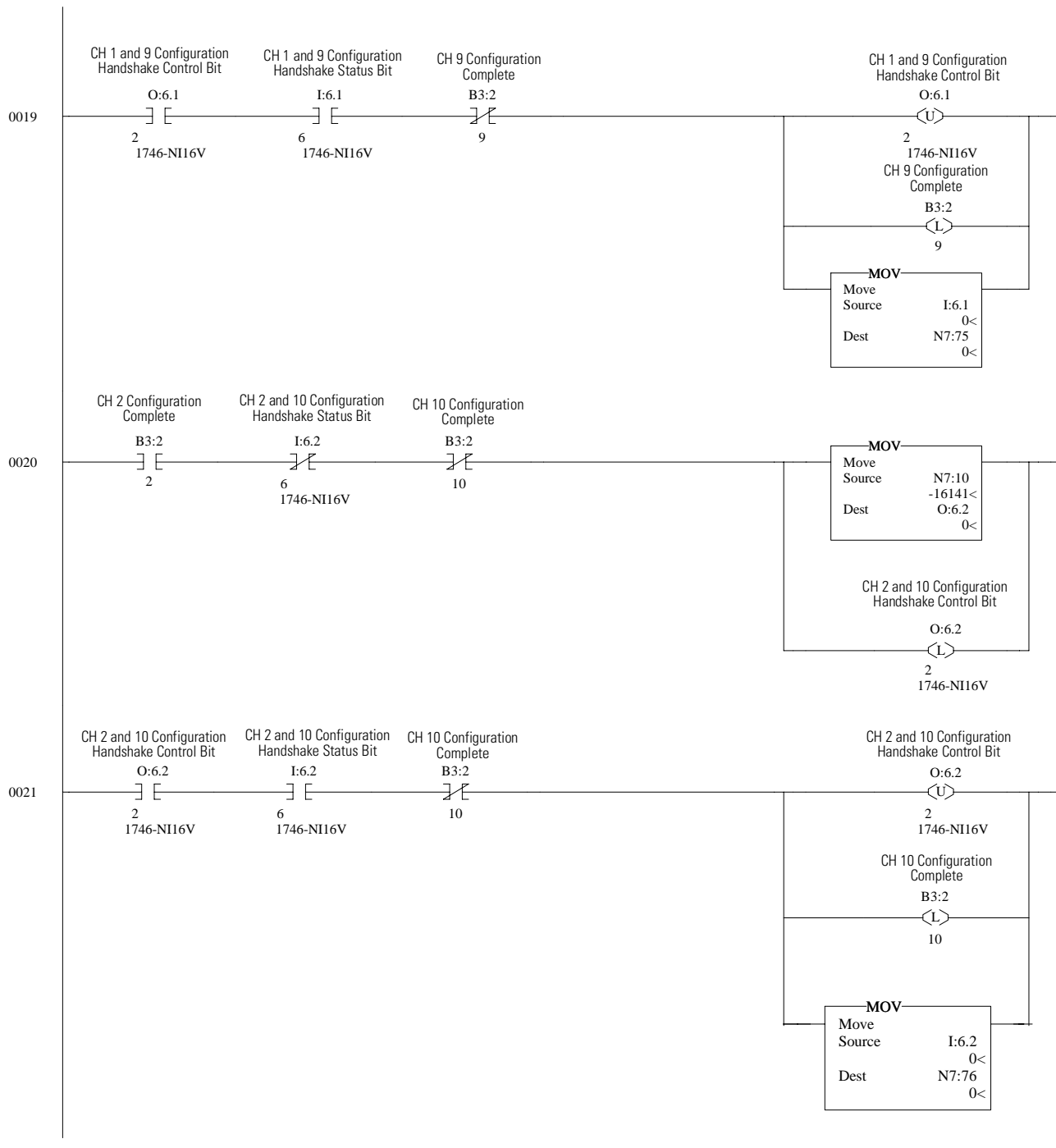
File 3 (Continued)



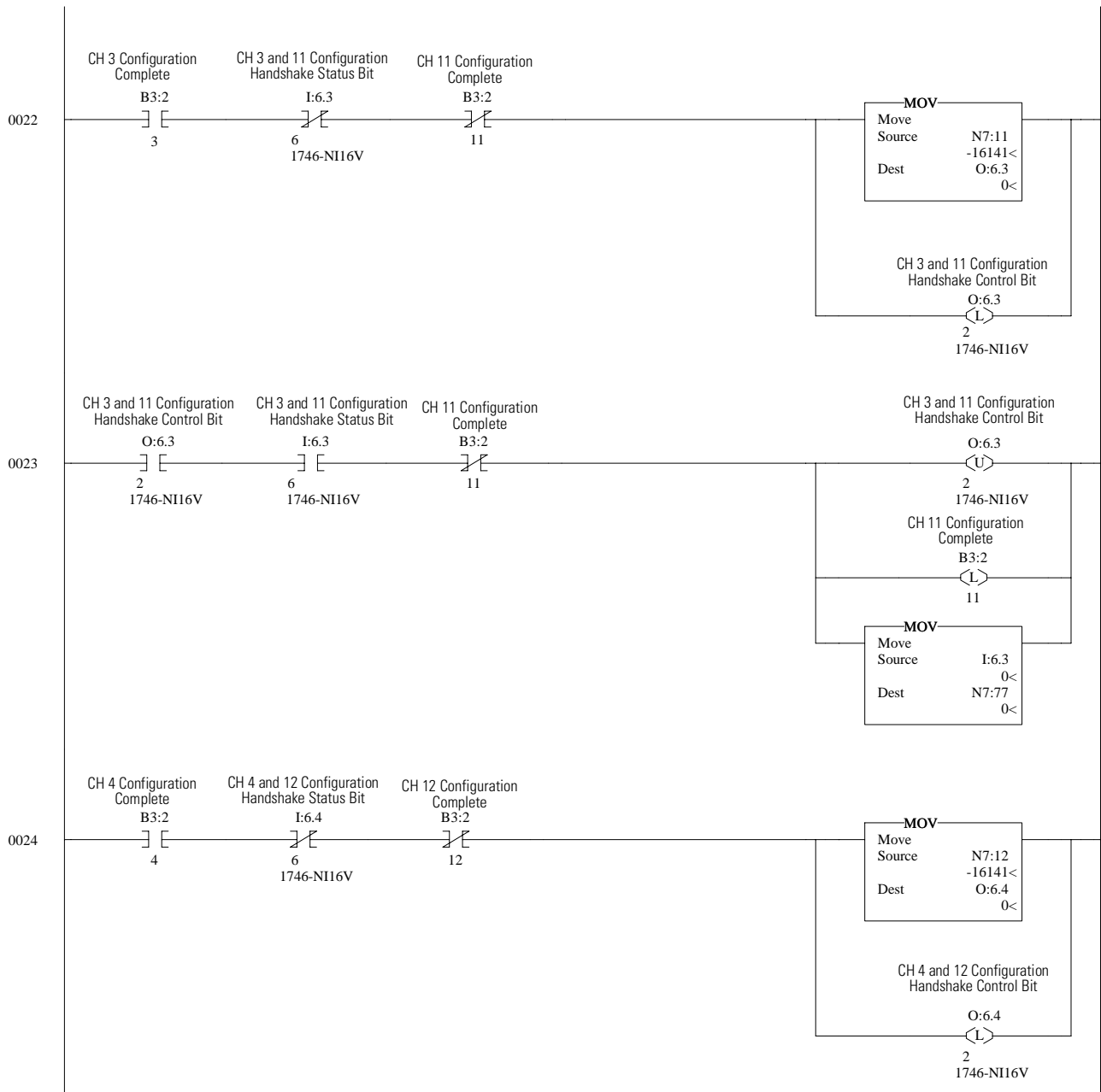
File 3 (Continued)



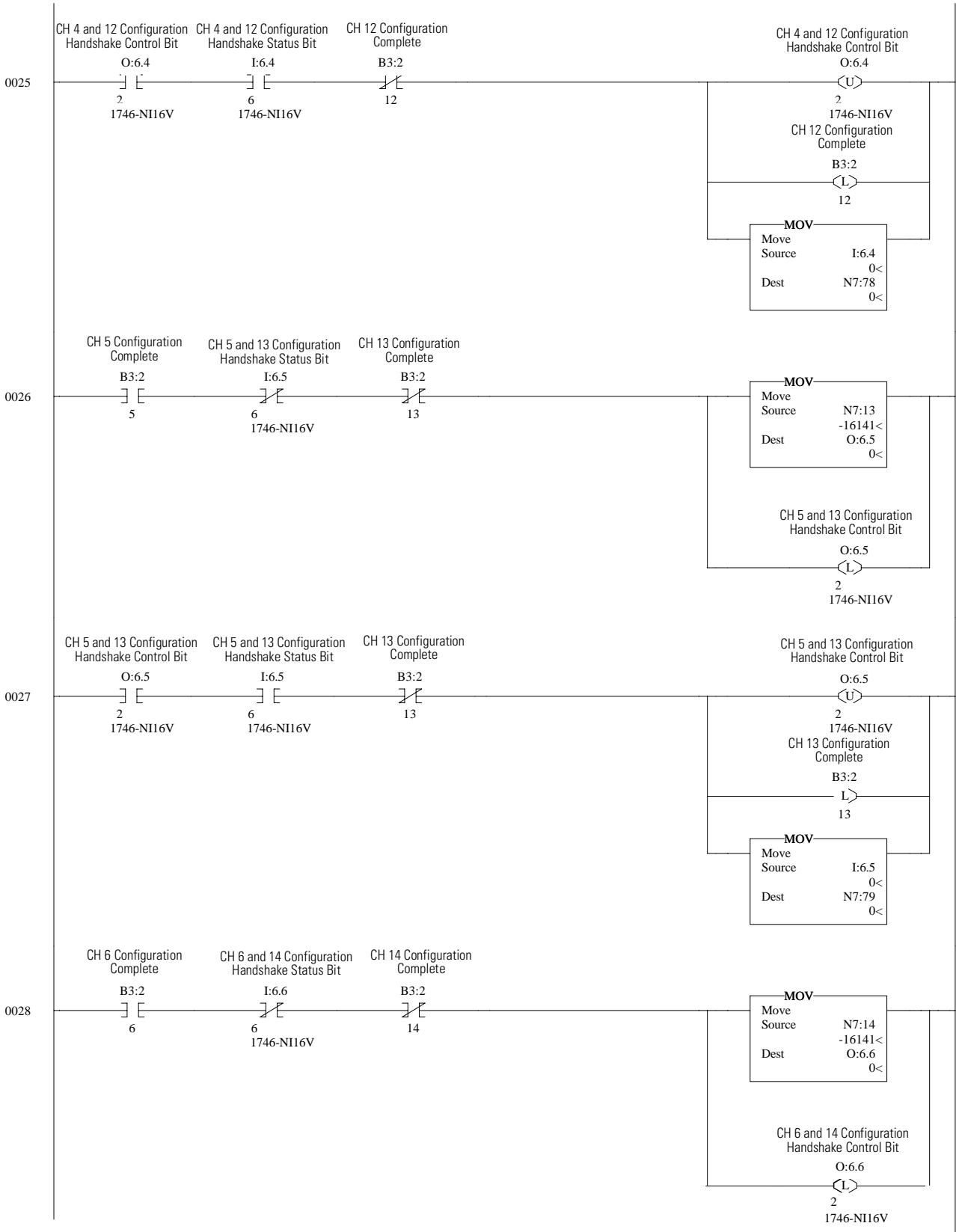
File 3 (Continued)



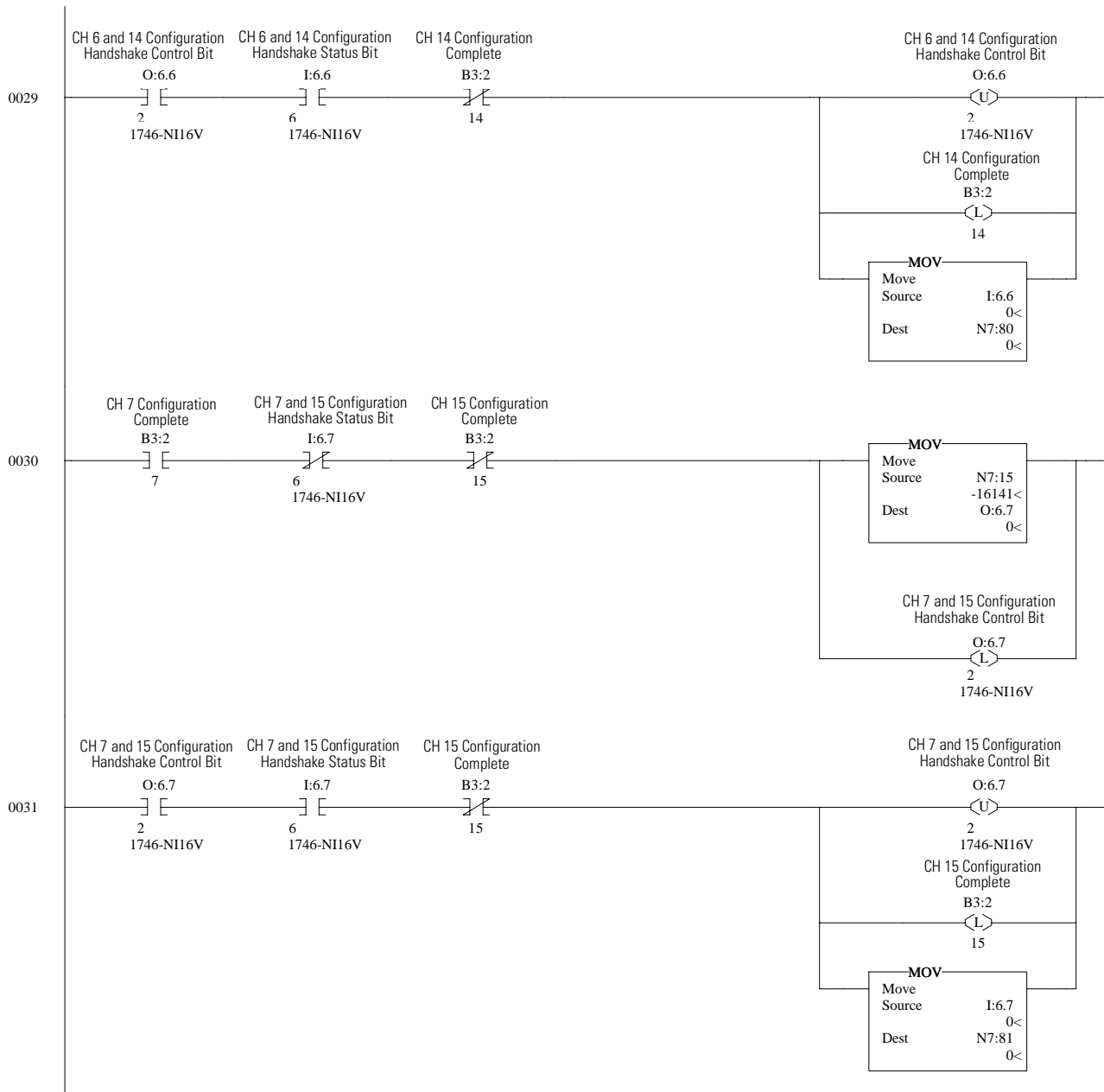
File 3 (Continued)



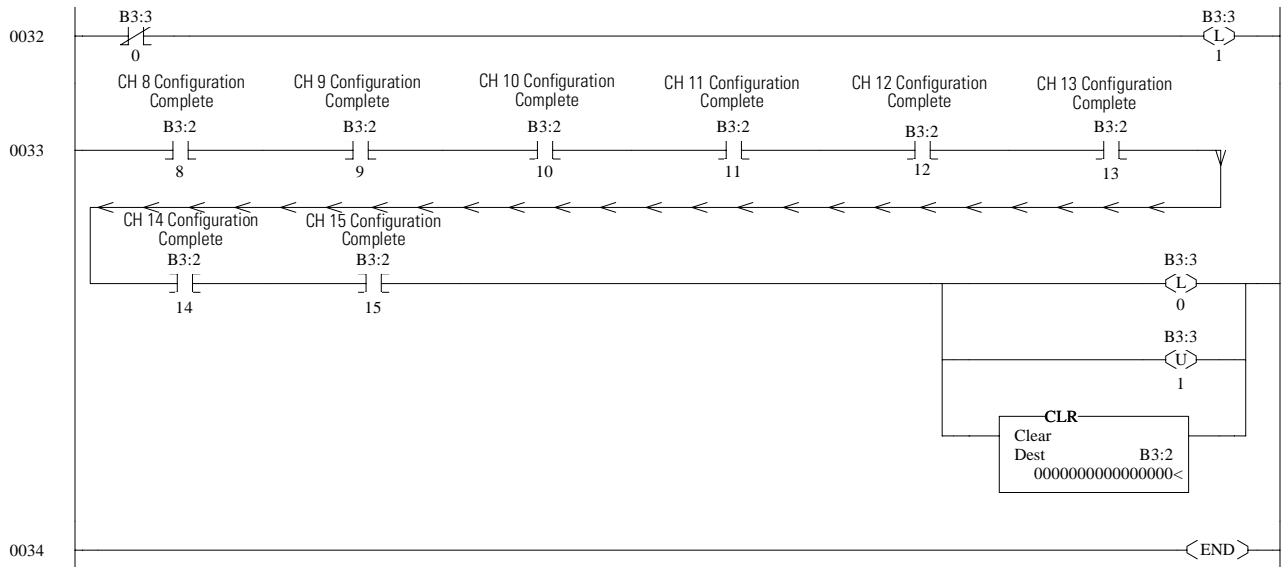
File 3 (Continued)



File 3 (Continued)



File 3 (Continued)



The following table shows configuration and control words for the ladder program. The table is showing integer file N7 in the Decimal Radix. Words N7:0 through N7:15 contain the configuration words for analog channels 0 to 15 to send analog data to the controller. These configurations and control words must be viewed in the Binary Radix because they are bit-mapped. Please refer to Chapter 5, Channel Configuration, Data and Status for an explanation of each bit in these words. For this example, each channel has been configured for 0 to 10vdc, 1746-NI14 data format and a filter frequency of 60 Hz.

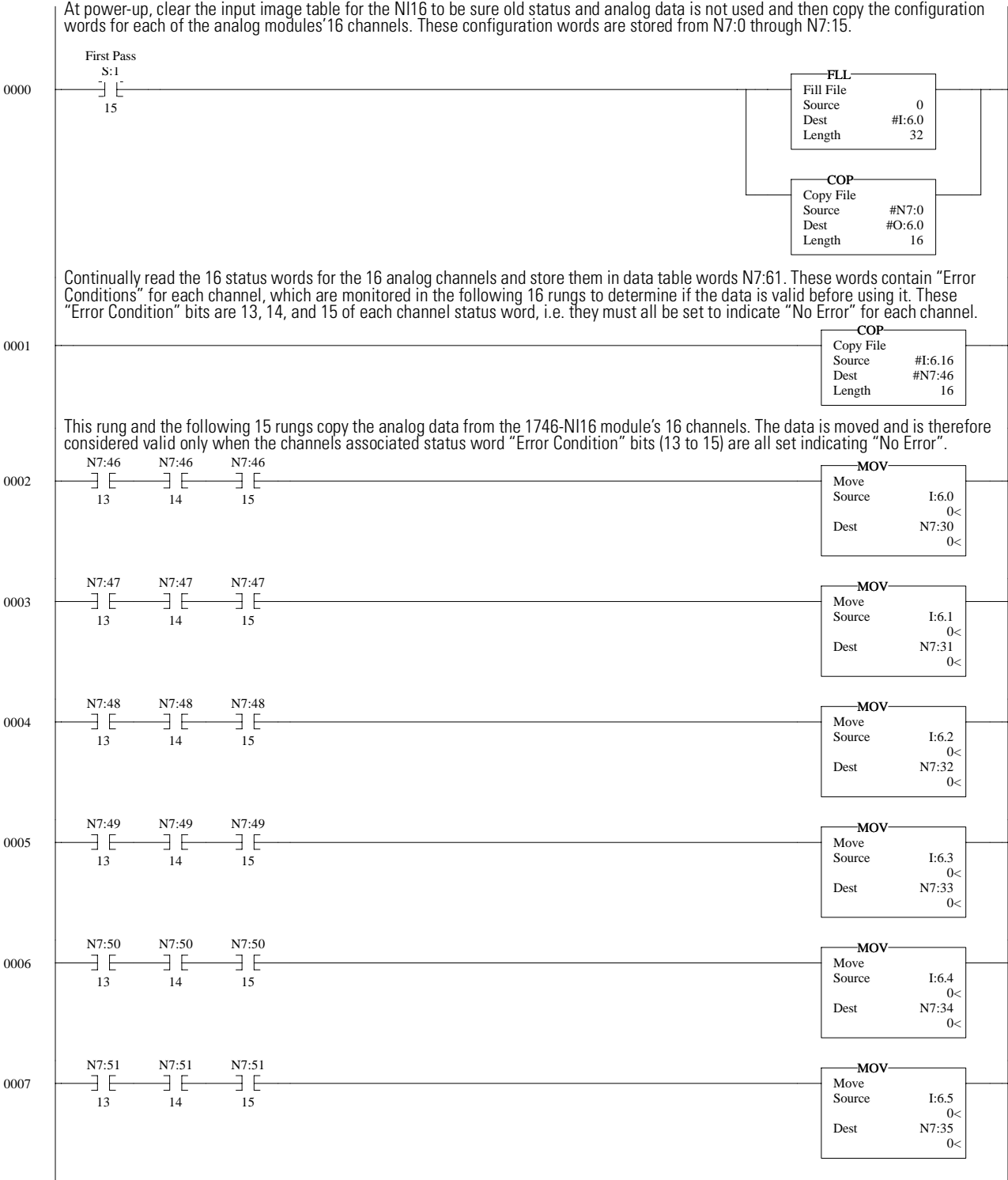
Data File N7

| Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| N7:0 | -16142 | -16142 | -16142 | -16142 | -16142 | -16142 | -16142 | -16142 | -16141 | -16141 |
| N7:10 | -16141 | -16141 | -16141 | -16141 | -16141 | -16141 | 0 | 0 | 0 | 0 |
| N7:20 | -32768 | -32768 | -32768 | -32768 | -32768 | -32768 | -32768 | -32768 | -32767 | -32767 |
| N7:30 | -32767 | -32767 | -32767 | -32767 | -32767 | -32767 | 0 | 0 | 0 | 0 |

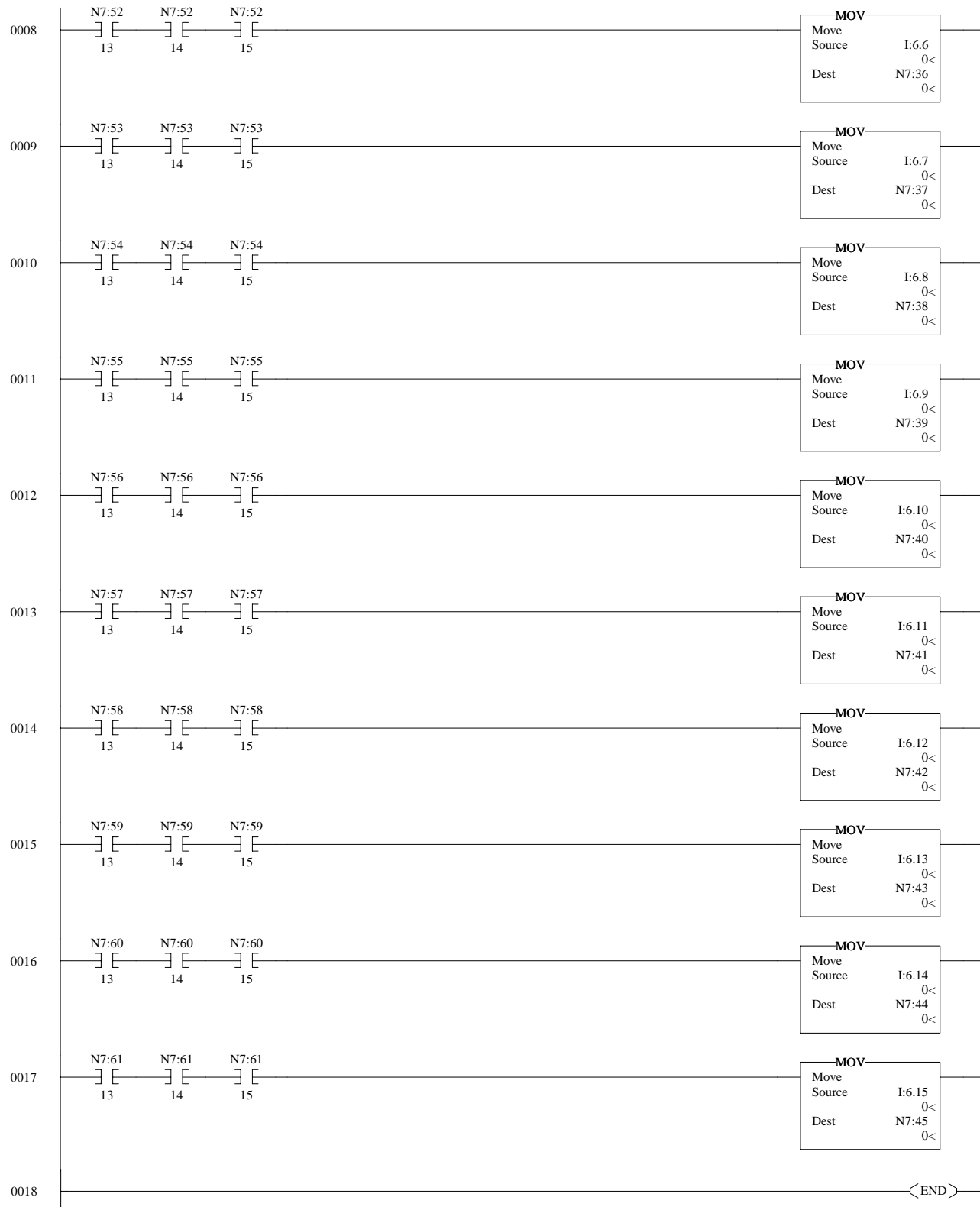
Class 3 Example

The following ladder logic program configures all 16 channels of a 1747-NI16 analog input module. It then monitors the module status information and uses the analog data from the 16 channels when status for each channel is good. In Class 3 mode, the processor can read/write up to 32 I/O words from the module. In this mode, the SLC 5/02 or later processor can configure all 16 channels with one COPY instruction. In addition, one copy instruction can be used to constantly monitor status and, at the same time, a second copy instruction can be used to bring the analog data into the SLC processor. The status data can then be used to qualify the ladder rungs that use the analog data. This ensures that the data is not used if configuration errors, open-circuit conditions, or over- and under-voltage conditions exist.

Ladder File 2



File 2 (Continued)



Data File N7

The table below is Data Table File N7. Words N7:0 through N7:15 are the configuration words for channels 0 through 15 of the NI16 module in the decimal radix. Refer to Chapter 5, Channel Configuration, Data and Status for an explanation of each bit in these words. Since this is bit-mapped data, it must be viewed in the binary radix. For this example, each analog channel has been configured for $\pm 10\text{Vdc}$ input type, a data format of 1746-NI4 and a filter frequency of 60Hz.

| offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| N7:0 | -16192 | -161992 | -16192 | -16192 | -16192 | -16192 | -16192 | -16192 | -16192 | -16192 |
| N7:10 | -16192 | -16192 | -16192 | -16192 | -16192 | -16192 | | | | |

Specifications

This appendix lists the specifications for the 1746-NI16 Analog Input Module.

Electrical Specifications

| Description | Specification |
|--|--|
| Backplane Current Consumption | 125 mA at 5V dc 75 mA at 24V dc |
| Backplane Power Consumption | 2.425W maximum (0.625W at 5V dc, 1.8W at 24V dc) |
| Number of Channels | 16 (backplane isolated) |
| I/O Chassis Location | Any I/O module slot except slot 0 |
| A/D Conversion Method | Sigma - Delta |
| Input Filtering | Low-pass digital filter with programmable filter frequencies |
| Normal Mode Rejection (between [+] input and [-] input) | >80 dB at 50/60 Hz >75 dB at dc >100 dB at 50/60 Hz |
| Common Mode Rejection (between inputs and chassis ground) | Greater than or equal to 75 dB at DC Greater than or equal to 100 dB at 50/60 Hz |
| Input Filter Frequencies | 6 Hz, 10 Hz, 20 Hz, 40 Hz, 60 Hz, 80 Hz, 100 Hz, 250 Hz |
| Isolation | 500V ac isolation for 1 second |
| Common-Mode Voltage Range | ±10.25V relative to analog common terminal (20.5V maximum between any two signal input terminals) |

Physical Specifications

| Description | | Specification | |
|------------------------------------|-------|--|---------|
| LED Indicators | | 5 green status indicators one for each group of 4 channels, and one for module status | |
| Module ID Code | | Class 1 | Class 3 |
| | NI16V | 3505 | 10406 |
| | NI16I | 3504 | 10403 |
| Recommended Cable | | Belden #8761 or equivalent | |
| Maximum Wire Size | | Two 14 AWG wires per terminal | |
| Maximum Cable Impedance | NI16V | Voltage Source (with less than 10Ω impedance): 1250Ω maximum loop impedance, for 1LSB error | |
| | NI16I | Current Source (transmitter properly wired to its power supply): 249Ω maximum loop impedance, to meet common-mode voltage requirements | |
| Terminal Block | | Removable, Allen-Bradley spare part Catalog Number 1746-RT25G | |
| Allen-Bradley Prewired Cables | | 1492-ACAB005A46, 0.5m (1.6 ft.) 1492-ACAB010A46, 1.0 m (3.3 ft.) 1492-ACAB025A46, 2.5 m (8.2 ft.) 1492-ACAB050A46, 5.0 m (16.4 ft.) | |
| Allen-Bradley User Terminal Blocks | | 1492-AIFM8-3 1492-AIFM16-F-3 | |

Environmental Specifications

| Description | Specification |
|--------------------------------------|--|
| Operating Temperature | 0°C to +60°C (+32°F to +140°F) in any slot except slot 0 |
| Storage Temperature | -40°C to +85°C (-40°F to +185°F) |
| Relative Humidity | 5% to 95% (without condensation) |
| Agency Certification | UL listed C-UL approved CE compliant for all applicable directives |
| Hazardous Environment Classification | Class I Division 2 Hazardous Environment |

Input Specifications

| Description | | Specification |
|--|-------|---|
| Type of Input (Selectable) | NI16V | ±10V dc, 1 to 5V dc, 0 to 5V dc, 0 to 10V dc, |
| | NI16I | 0 to 20 mA, 4 to 20 mA, ±20 mA, 0 to 1 mA |
| Type of Data (Selectable) | | Engineering Units Scaled-for-PID Proportional Counts (-32,768 to +32,767 range) Proportional Counts (User-Defined Range, Class 3 only) 1746-NI4 Data Format |
| Input Impedance | NI16V | 20 MΩ |
| | NI16I | 249 Ω |
| Maximum Voltage Input without Damage | NI16V | ±30V between any two signal terminals |
| | NI16I | ±8V between any two signal terminals |
| Current Input (maximum) | | ±30 mA (Between analog com and any input terminal) |
| Time to Detect Open Circuit | | Less than 5 seconds |
| Module Update Time | | See Chapter 4, Channel Filter Frequency Selection, page 4-6 |
| Input Resolution | NI16V | 312 μA |
| | NI16I | 640 nA |
| Display Resolution | | 1 mV or 1 μA |
| Module Error Over Full Temperature Range (0°C to +60°C, +32°F to +140°F) | NI16V | Voltage input types (±10V dc, 1 to 5V dc, 0 to 5V dc, 0 to 10V dc): 0.1% |
| | NI16I | Current input types (0 to 20 mA, 4 to 20 mA, 0 to 1 mA, ±20 mA): 0.3% |
| Input Offset Drift with Temperature | NI16V | Voltage input type: 90 μV/°C offset drift with temperature |
| | NI16I | Current input type: 360 nA/°C offset drift with temperature |
| Gain Drift with Temperature | NI16V | 15 ppm/°C |
| | NI16I | 20 ppm/°C |
| Calibrated Accuracy at 25°C | NI16V | Better than 0.05% of range |
| | NI16I | Better than 0.15% of range |

Configuration Worksheet

The following worksheet is provided to help you configure each of the channels on your module. See Chapter 5 for detailed configuration information.

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Bit Number |
|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|------------|
| | | | | | | | | | | | | 0 | | | | Channel 0 |
| | | | | | | | | | | | | 0 | | | | Channel 1 |
| | | | | | | | | | | | | 0 | | | | Channel 2 |
| | | | | | | | | | | | | 0 | | | | Channel 3 |
| | | | | | | | | | | | | 0 | | | | Channel 4 |
| | | | | | | | | | | | | 0 | | | | Channel 5 |
| | | | | | | | | | | | | 0 | | | | Channel 6 |
| | | | | | | | | | | | | 0 | | | | Channel 7 |
| | | | | | | | | | | | | 0 | | | | Channel 8 |
| | | | | | | | | | | | | 0 | | | | Channel 9 |
| | | | | | | | | | | | | 0 | | | | Channel 10 |
| | | | | | | | | | | | | 0 | | | | Channel 11 |
| | | | | | | | | | | | | 0 | | | | Channel 12 |
| | | | | | | | | | | | | 0 | | | | Channel 13 |
| | | | | | | | | | | | | 0 | | | | Channel 14 |
| | | | | | | | | | | | | 0 | | | | Channel 15 |

- Class 1 Channel Configuration
- Class 1 Handshaking
- Not Used
- Input Type
- Data Format
- Calibration
- Filter Frequency
- Channel Enable

Bit Definitions:

| | | | | | |
|-------------------|--------------------------------------|---|--|---|--|
| Bit 15 | Channel Enable | 0 = channel disabled | 1 = channel enabled | | |
| Bits 14-12 | Filter Frequency | 000 = 6 Hz 001 = 10 Hz | 010 = 20 Hz 011 = 40 Hz | 100 = 60 Hz 101 = 80 Hz | 110 = 100 Hz 111 = 250 Hz |
| Bits 11-9 | Calibration | 000 = exit calibration (normal run mode) | 001 = enter calibration | 011 = perform zero calibration | 101 = perform full scale calibration |
| Bits 8-6 | Data Format | Class 1 and Class 3 | | | Class 3 Only |
| | | 000 = engineering units 001 = scaled-for-PID | 010 = proportional counts 011 = 1746-NI4 data format | 100 = user-defined scaling 0 101 = user-defined scaling 1 | 110 = user-defined scaling 2 111 = user-defined scaling 3 |
| Bits 5-4 | Input Type | 000 = ±10V dc or ±20 mA 001 = 1-5V dc or 4-20 mA | 010 = 0 to 5V dc or 0 to 1 mA 011 = 0 to 10V dc or 0 to 20 mA | | |
| Bits 3 | Not Used | | | | |
| Bit 2 | Class 1 Handshaking | 0 = to reset status bit 6 | | 1 = transmit channel configuration | |
| Bits 1-0 | Class 1 Data or Status Configuration | 00 = read data for channels 0 to 7 01 = read data for channels 8 to 15 | | 10 = read status for channels 0 to 7 11 = read status for channels 8 to 15 | |

Two's Complement Binary Numbers

The SLC 500™ processor memory stores 16-bit binary numbers. Two's complement binary is used when performing mathematical calculations internal to the processor. Analog input values from the analog modules are returned to the processor in 16-bit two's complement binary format. For positive numbers, the binary notation and two's complement binary notation are identical.

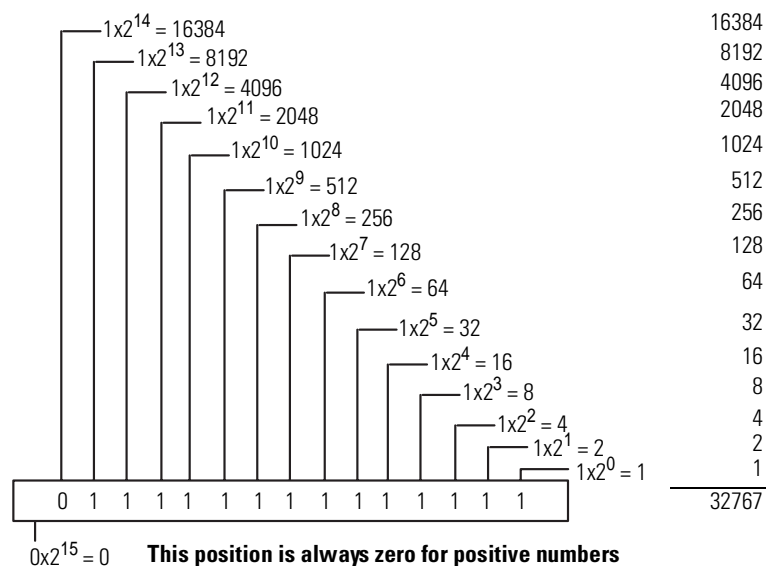
As indicated in the figure on the next page, each position in the number has a decimal value, beginning at the right with 2^0 and ending at the left with 2^{15} . Each position can be 0 or 1 in the processor memory. A 0 indicates a value of 0; a 1 indicates the decimal value of the position. The equivalent decimal value of the binary number is the sum of the position values.

Positive Decimal Values

The far left position is always 0 for positive values. As indicated in the figure below, this limits the maximum positive decimal value to 32,767 (all positions are 1 except the far left position). For example:

$$0000\ 1001\ 0000\ 1110 = 2^{11} + 2^8 + 2^2 + 2^2 + 2^2 = 2048 + 256 + 8 + 4 + 2 = 2318$$

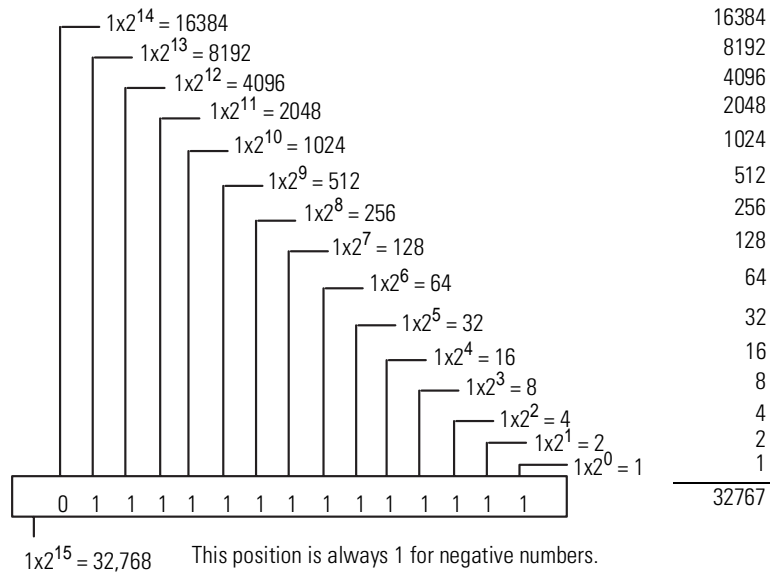
$$0010\ 0011\ 0010\ 1000 = 2^{13} + 2^9 + 2^8 + 2^5 + 2^3 = 8192 + 512 + 256 + 32 + 8 = 9000$$



Negative Decimal Values

In two's complement notation, the far left position is always 1 for negative values. The equivalent decimal value of the binary number is obtained by subtracting the value of the far left position, 32,768, from the sum of the values of the other positions. In the figure below (all positions are 1), the value is $32,767 - 32,768 = -1$. For example:

$$\begin{aligned}
 &1111\ 1000\ 0010\ 0011 = \\
 &(2^{14} + 2^{13} + 2^{12} + 2^{11} + 2^5 + 2^1 + 2^0) - 2^{15} = \\
 &(16384 + 8192 + 4096 + 2048 + 32 + 2 + 1) - 32,768 = \\
 &30,755 - 32,768 = -2013.
 \end{aligned}$$



Calibration

The module should be calibrated to the following values to adhere to the “Module Error Over Full Temperature Range” specifications in Appendix A.

| Module Type | Calibration Voltage or Current Range | |
|-------------|--------------------------------------|------------------------|
| | Low Calibration Value | High Calibration Value |
| 1746-NI16V | -0.005 V to +0.005 V | +10.245 V to +10.255 V |
| 1746-NI16I | -0.03 mA to +0.03 mA | +20.97 mA to +21.03 mA |

Calibration Sequence

The module returns a faulty calibration error if the order of the calibration sequence is not performed as expected. The calibration sequence is as follows:

1. Disable the channel to be calibrated by setting bit 15 to 0.
2. Set bit 9 equal to 1 in the configuration word to enter the calibration mode.
3. Apply a low calibration value from the appropriate range, according to the table above.
4. Set bit 10 to 1 to accept this input as the new low calibration value.
5. Verify that bit 8 in the appropriate status word has changed to a 1, signifying that the low value calibration was accepted.
6. Change bit 10 in the calibration word back to a 0.
7. Apply a high calibration value to the channel to be calibrated from the appropriate range according to the table above.
8. Set bit 11 to 1 to accept this input as the new high calibration value.
9. Verify that bit 9 in the appropriate status word has changed to a 1 signifying the high value calibration was accepted.
10. Change bit 11 in the calibration word back to a 0.
11. Change bit 9 in the configuration word back to a 0 to exit the calibration mode.

Existing calibration values can be overwritten to re-calibrate a channel.

The following terms and abbreviations are used throughout this manual. For definitions of terms not listed here refer to *Allen-Bradley's Industrial Automation Glossary*, Publication AG-7.1.

A/D - Refers to the analog to digital converter inherent to the module. The converter produces a digital value whose magnitude is proportional to the instantaneous magnitude of an analog input signal.

analog input module - An I/O module that contains circuits that convert analog dc input signals to digital values that can be manipulated by the processor.

attenuation - The reduction in the magnitude of a signal as it passes through a system.

backplane -A printed circuit board, at the back of the chassis, that provides electrical interconnection between the modules inserted into the chassis.

channel - Refers to one of eight, small-signal analog input interfaces available on the module's terminal block. Each channel is configured for connection to a voltage or current source input device and has its own data and diagnostic status words.

channel update time - The time required for the module to sample and convert the input signals of one enabled input channel and update the channel data word.

chassis - A hardware assembly that houses devices such as I/O modules, adapter modules, processor modules, and power supplies.

common mode rejection ratio - The ratio of a device's differential voltage gain to common mode voltage gain. Expressed in dB, CMRR is a comparative measure of a device's ability to reject interference caused by a voltage common to its input terminals relative to ground.
 $CMRR = 20 \log_{10} (V_1/V_2)$

common mode voltage - A voltage that appears in common at both input terminals of a differential analog input with respect to ground.

configuration word - Contains the channel configuration information needed by the module to configure and operate each channel. Information is written to the configuration word through the logic supplied in your ladder program.

dB - (decibel) A logarithmic measure of the ratio of two signal levels.

data word - A 16-bit integer that represents the value of the analog input channel. The channel data word is valid only when the channel

is enabled and there are no channel errors. When the channel is disabled, the channel data word is cleared (0).

digital filter - A filter implemented in firmware, using discrete, sampled data of the input signal.

filter - A device that passes a signal or range of signals and eliminates all others.

filter frequency - (-3 dB frequency) The user-selectable frequency.

full scale error - (gain error) The difference in slope between the actual and ideal analog transfer functions.

full scale range - (FSR) The difference between the maximum and minimum specified analog input values.

gain drift - The change in full scale transition voltage measured over the operating temperature range of the module.

input data scaling -The data formats that you select to define the logical increments of the channel data word. These may be scaled-for-PID, or Engineering Units, which are automatically scaled. They may also be proportional counts, which you must calculate to fit the resolution of the quantity being measured in your application.

input image - The input from the 1746-NI16 module to the SLC500™ processor. The input image contains the module data words and status words.

local configuration - A control system where all the chassis are located within several feet of the processor, and chassis-to-chassis communication is via a 1746-C7 or 1746-C9 ribbon cable.

LSB - (Least Significant Bit) The bit that represents the smallest value within a string of bits.

module scan time - same as *module update time*

module update time - The time required for the module to sample and convert the input signals of all enabled input channels and make the resulting data values available to the SLC500 processor.

multiplexer - An switching system that allows several input signals to share a common A/D converter.

normal mode rejection - (differential mode rejection) A logarithmic measure, in dB, of a device's ability to reject noise signals between or among circuit signal conductors.

output image - The output from the SLC processor to the 1746-NI16 module. The output image contains the module configuration information. Each output word configures a single channel.

remote configuration - A control system where the chassis can be located several thousand feet from the processor chassis. Chassis communication is via the 1747-SN Scanner and 1747-ASB Remote I/O Adapter.

resolution - The smallest detectable change in a measurement, typically expressed in engineering units (e.g. 1 mV) or as a number of bits. For example a 12-bit system has 4,096 possible output states. It can, therefore, measure 1 part in 4096.

scaling - The process of changing a quantity from one notation to another.

status word - Contains status information about the channel's current configuration and operational state. You can use this information in your ladder program to determine whether the channel data word is valid.

step response time - This is the time required for the channel data word signal to reach a specified percentage of its expected final value, given a large step change in the input signal.

transducer - A device that converts one energy form to another (e.g., mechanical to electrical). When a transducer is actuated by signals from one system or medium, it can supply a related signal to the other system or medium.

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www.rockwellautomation.com

Power, Control and Information Solutions Headquarters

Americas: Rockwell Automation, 1201 South Second Street, Milwaukee, WI 53204-2496 USA, Tel: (1) 414.382.2000, Fax: (1) 414.382.4444

Europe/Middle East/Africa: Rockwell Automation, Vorstlaan/Boulevard du Souverain 36, 1170 Brussels, Belgium, Tel: (32) 2 663 0600, Fax: (32) 2 663 0640

Asia Pacific: Rockwell Automation, Level 14, Core F, Cyberport 3, 100 Cyberport Road, Hong Kong, Tel: (852) 2887 4788, Fax: (852) 2508 1846

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