



Allen-Bradley

Thermocouple/mV Isolated Input Module

Catalog Number 1746-INT4

User Manual

**Rockwell
Automation**

Important User Information

Solid state equipment has operational characteristics differing from those of electromechanical equipment. Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls (publication SGI-1.1 available from your local Rockwell Automation sales office or online at <http://literature.rockwellautomation.com>) describes some important differences between solid state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

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Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

WARNING 	Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.
ATTENTION 	Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence
SHOCK HAZARD 	Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.
BURN HAZARD 	Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.

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Use This Manual

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
- Terms and abbreviations
- Conventions used in this manual
- Allen-Bradley support

Who Should Use This Manual

Use this manual if you are responsible for designing, installing, programming, or troubleshooting control systems that use Allen-Bradley small logic controllers.

You should have a basic understanding of SLC 500 products. You should understand programmable controllers and be able to interpret the ladder logic instructions required to control your application. If you do not, contact your local Allen-Bradley representative for information on available training courses before using this product.

Purpose of This Manual

This manual is a reference guide for the module. The manual:

- gives you an overview of system operation.
- explains the procedures you need to install and wire the module at the application site.
- provides ladder programming examples.
- provides an application example of how this input module can be used to control a process.

Additional Resources

The following documents contain information that may be helpful to you as you use Allen-Bradley SLC products. To obtain a copy of any of the Allen-Bradley documents listed, contact your local Allen-Bradley office or distributor.

Resource	Description
SLC 500 Systems Selection Guide, publication 1747-SG001	An overview of the SLC 500 family of products
SLC 500 Module Hardware Style User Manual, publication 1747-UM011	A description on how to install and use your modular SLC 500 programmable controller
Installation & Operation Manual for Fixed Hardware Style Programmable Controllers, publication 1747-6.21	A description on how to install and use your fixed SLC 500 programmable controller
SLC 500 Instruction Set Reference Manual, publication 1747-RM001	A reference manual that contains status file data, instruction set, and troubleshooting information about the software
SLC 500 4-Channel Analog I/O Modules User's Manual, publication 1746-UM005	A resource manual and user's guide containing information about the analog modules used in your SLC 500 system.
Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1	In-depth information on grounding and wiring Allen-Bradley programmable controllers
Application Considerations for Solid-State Controls. publication SGI-1.1	A description of important differences between solid-state programmable controller products and hard-wired electromechanical devices
National Electrical Code, published by the National Fire Protection Association of Boston, MA	An article on wire sizes and types for grounding electrical equipment

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.

Module Overview

This chapter describes the thermocouple/millivolt isolated input module and explains how the SLC controller reads thermocouple or millivolt analog input data from the module. The following information is included:

- Compliance with European Union Directives
- General description and hardware features
- An overview of system and module operation
- Block diagram of channel input circuits

Compliance with European Union Directives

If this product has the CE mark, it is approved for installation within the European Union and EEA regions. It has been designed and tested to meet the following directives.

EMC Directive

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

This product is intended for use in an industrial environment.

Low Voltage Directive

This product is tested to meet Council Directive 73/23/EEC Low Voltage, by applying the safety requirements of EN 61131-2 Programmable Controllers, Part 2 — Equipment Requirements and Tests.

For specific information required by EN 61131-2, see the appropriate sections in this publication, as well as the Industrial Automation Wiring and Grounding Guidelines (for noise immunity), publication 1770-4.1.

This equipment is classified as open equipment and must be mounted in an enclosure during operation to provide safety protection.

General Description

The module stores digitally-converted thermocouple and/or millivolt (mV) analog data in its image table for retrieval by all fixed and modular SLC 500 processors. The module supports connections from any combination of up to four thermocouple and/or mV analog sensors.

Input Ranges

The following tables define thermocouple types and associated temperature ranges and the millivolt analog-input signal ranges that each of the module's input channel supports.

Refer to the specifications in Appendix A to determine the practical temperature range of your thermocouple.

Thermocouple Temperature Ranges

Type	°C Temperature Range	°F Temperature Range
C	0...2317	32... 4201
D	0... 2317	32...4201
J	-210...760	-346...1400
K	-270...1370	-454...2498
T	-270...400	-454...752
B	300...1820	572...3308
E	-270...1000	-454...1832
R	0...1768	32...3214
S	0...1768	32...3214
N	0...1300	32...2372
CJC Sensor	0...85	32...185

Millivolt Input Ranges

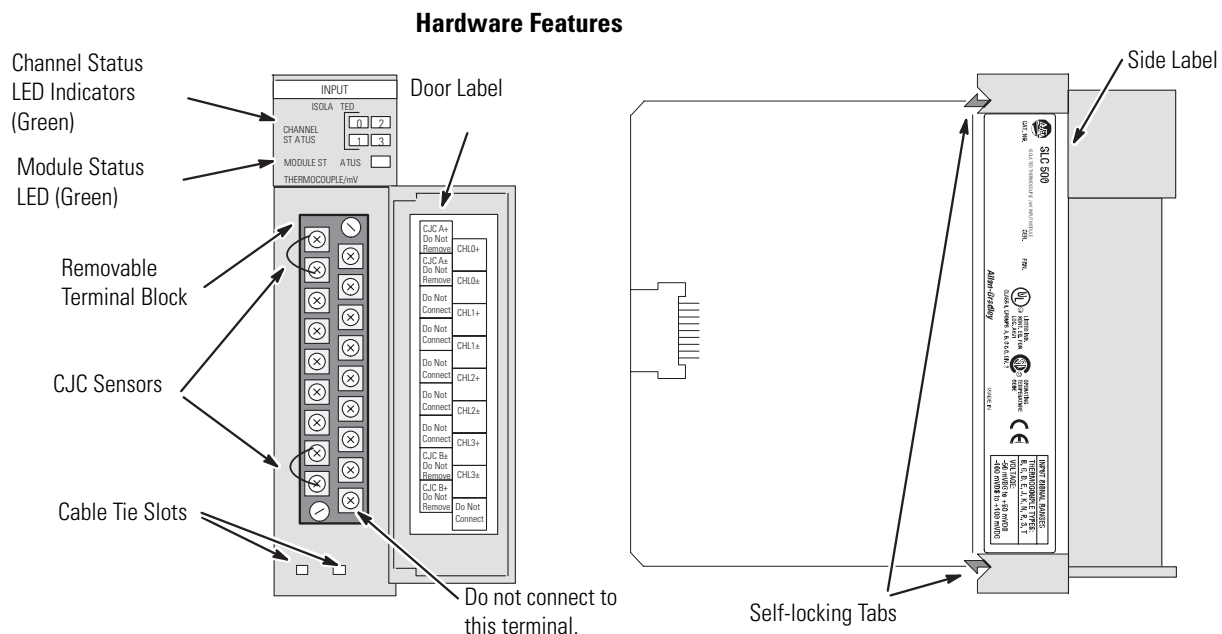
-50...50 mV
-100...100 mV

Each input channel is individually configurable for a specific input device, and provides open-circuit, over-range, and under-range detection and indication.

Hardware Features

The module fits into any single slot for I/O modules in either an SLC 500 modular system or an SLC 500 fixed system expansion chassis (1746-A2). It is a Class 1⁽¹⁾ module (uses eight input words and eight output words).

The module contains a removable terminal block providing connections for four thermocouple and/or analog input devices. There are two cold-junction compensation (CJC) sensors that compensate for the cold-junction at ambient temperature rather than at freezing 0 °C (32 °F). There are no output channels on the module. You configure the module with software rather than with jumpers or switches.



Hardware Features

Hardware	Function
Channel status LED indicators	Display operating and fault status of channels 0, 1, 2, and 3
Module status LED	Displays operating and fault status of the module
Side label (nameplate)	Provides module information
Removable terminal block	Provides electrical connection to input devices
Door label	Permits easy terminal identification
Cable tie slots	Secure input wiring at the module
Self-locking tabs	Secure module in chassis slot

⁽¹⁾ Requires use of Block Transfer in a remote I/O configuration.

Diagnostic LED Indicator

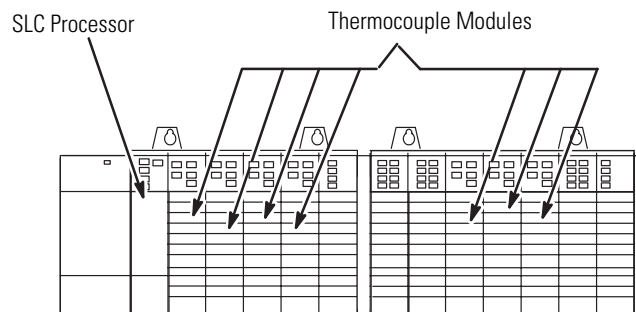
The module contains diagnostic LED indicator that help you identify the source of problems that may occur when cycling power or during normal operation.

Power cycling and channel diagnostics are explained in Chapter 8, Module Diagnostics and Troubleshooting.

System Overview

The module communicates with the SLC 500 processor and receives +5V dc and +24V dc power from the system power supply through the parallel backplane interface. No external power supply is required. You may install as many thermocouple modules in the system as the power supply can support.

Module Placement



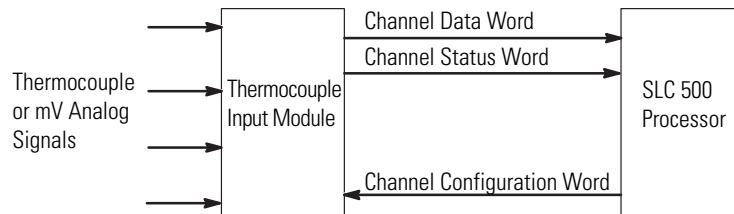
Each module channel can receive input signals from a thermocouple or a millivolt analog input device. You configure each channel to accept either one. When configured for thermocouple input types, the module converts analog input voltages into cold-junction compensated and linearized, digital temperature readings. The module uses the National Bureau of Standards (NBS) Monograph 125 and 161 based on IPTS-68 for thermocouple linearization.

When configured for millivolt analog inputs, the module converts analog values directly into digital counts. The module assumes that the mV input signal is linear.

System Operation

When you cycle power, the module checks its internal circuits, memory, and basic functions. During this time, the module status indicator remains off. If the module finds no faults, it turns on its module status indicator.

System Operation



After completing power cycle checks, the module waits for valid channel configuration data from your SLC ladder logic program (channel status LED indicators are off). After channel configuration data is transferred and channel enable bits are set for one or more channels, the module turns on its channel status LED indicators. Then it continuously converts the thermocouple or millivolt input to a value within the range you selected for the channel.

Each time the module reads an input channel, the module tests that data for a fault, for example, open-circuit, over-range, or under-range condition. If it detects such a condition, the module sets a unique bit in the channel status word and causes the channel status indicator to blink.

The SLC processor reads the converted thermocouple or millivolt data from the module at the end of the program scan, or when commanded by the ladder program. After the processor and module determine that the data transfer was made without error, the data can be used in your ladder program.

Module Operation

The module's input circuitry consists of four differential analog inputs, each with its own analog-to-digital (A/D) convertor. The A/D convertors read the analog input signals and convert them to digital counts. The input circuitry also continuously samples the CJC sensors and compensates for temperature changes at the cold-junction (terminal block).

See page 15 for a block diagram for the analog input circuitry.

Module Addressing

The module requires eight words each in the SLC processor's input and output image tables. Addresses for the module in slot e are as follows:

- I:e.0...3 thermocouple/mV data for channels 0...3, respectively
- I:e.4...7 status data for channels 0...3, respectively
- O:e.0...3 configuration data for channels 0...3, respectively
- O:e.4...7 reserved for future use. Do not use.

Compatibility with Thermocouple and Millivolt Devices and Cables

The module is compatible with the following NBS MN-125 and -161 standard types of thermocouples: B, C, D, E, J, K, N, R, S, and T and extension wire. The module is also compatible with a variety of mV devices with an output of ± 50 or ± 100 mV.

Refer to Appendices A and C for details.

To minimize interference from radiated electrical noise, we recommend twisted-pair and highly shielded cables.

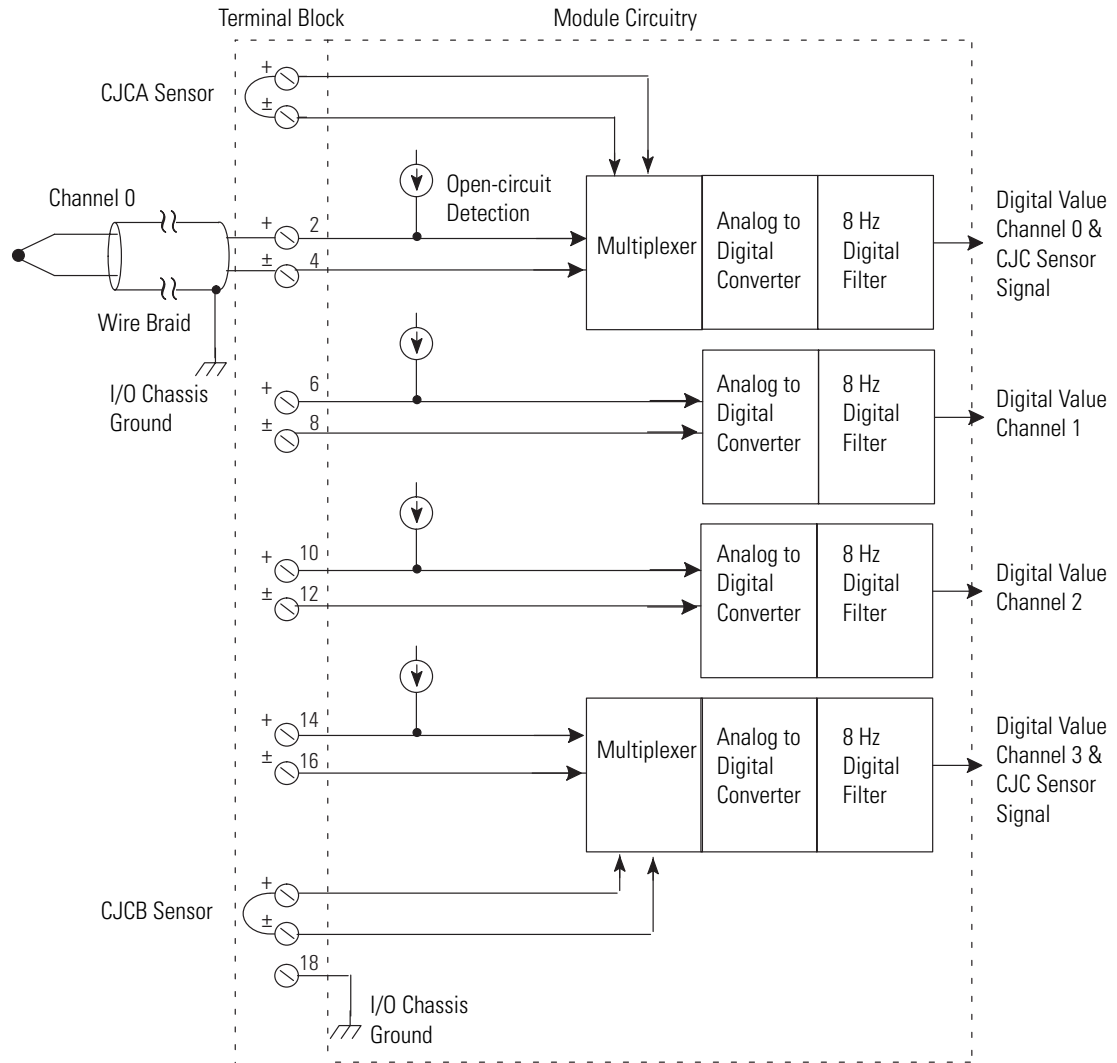
Minimizing Interference Devices

For This Type of Device	We Recommend This Cable (or equivalent)
Thermocouple type J	EIL Corp. J20-5-502
Thermocouple type K	EIL Corp. K20-5-510
Thermocouple type T	EIL Corp. T20-5-502
Other thermocouple types	Consult with EIL Corp or other manufacturers
Millivolt devices	Alpha Suprashield XTRA-GUARD 1 5121 (1pr), 5122 (2pr), 5131 (3pr), 5141 (4pr)

Block Diagram of Isolated-Channel Input Circuits

This illustration shows a block diagram for the analog input circuitry.

Block Diagram



Quick Start

Use this chapter as an abbreviated procedure for getting the module into operation or as an overview if you need the additional steps described in subsequent chapters. This chapter assumes that you understand the following things:

- SLC 500 products
- Electronic process control
- Ladder logic instructions

Because this chapter is a start-up guide, it does not contain detailed explanations. It does, however, refer to other chapters or to other SLC publications for more information.

If you are unsure of terms used or concepts presented in this chapter, always read the referenced chapters before trying to apply the information.

This chapter describes:

- what equipment you need.
- how to install and wire the module.
- how to set up one channel for thermocouple input.
- the state of the LED indicators at normal start-up.
- the channel status word.

Required Tools

Have the following tools and equipment ready:

- Medium blade screwdriver
- Medium cross-head screwdriver
- Thermocouple or millivolt sensor
- Thermocouple extension wire (if needed)
- The module
- I/O chassis
- SLC processor and power supply
- Programming software

Procedures

IMPORTANT

Follow these precautions to prevent damaging the module from electrostatic discharge:

- Before handling the module, rid yourself of electric charge by touching a grounded object.
 - Avoid touching connector terminations and circuit components.
 - Keep the module in its electrostatic shielded bag when not in use.
-

1. Unpack the module.

Unpack the module making sure that the contents include these items:

- Module (Catalog Number 1746-INT4)
- Removable terminal block (factory-installed on module) with CJC sensors attached

If the contents are incomplete, call your local Rockwell Automation representative for assistance.

2. Review the power requirements of the modules drawing power from the chassis power supply.

- The fixed, two-slot chassis supports two 1746-INT4 modules.

If combining a 1746-INT4 module with a different type of module, refer to Considerations for a Fixed Controller in Chapter 3.

- For a modular system, compute the total load on the system power supply.

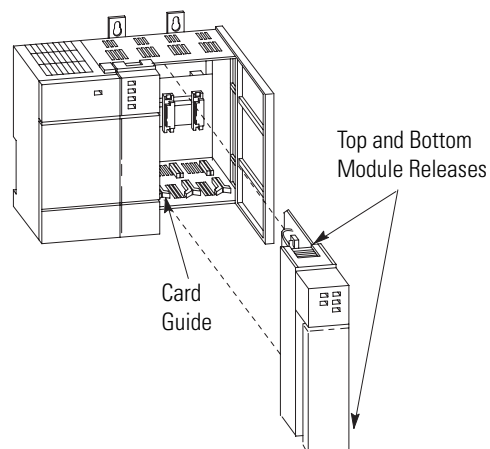
Refer to the procedure described in the SLC 500 Modular Hardware Style User Manual, publication 1747-UM011, or the SLC 500 Systems Selection Guide, publication 1747-SG001.

ATTENTION

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

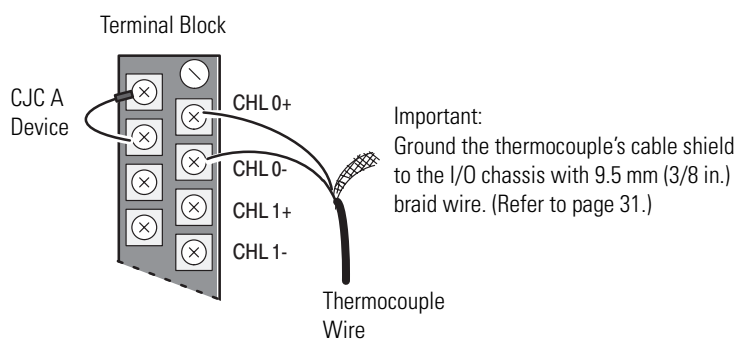
3. Install the module.

Make sure system power is off; then insert the module into the I/O chassis. In this example procedure, the module is inserted into slot 1.



4. Connect thermocouple wires to channel 0 on the module's terminal block.

Make sure both cold-junction compensation (CJC) devices are securely attached.

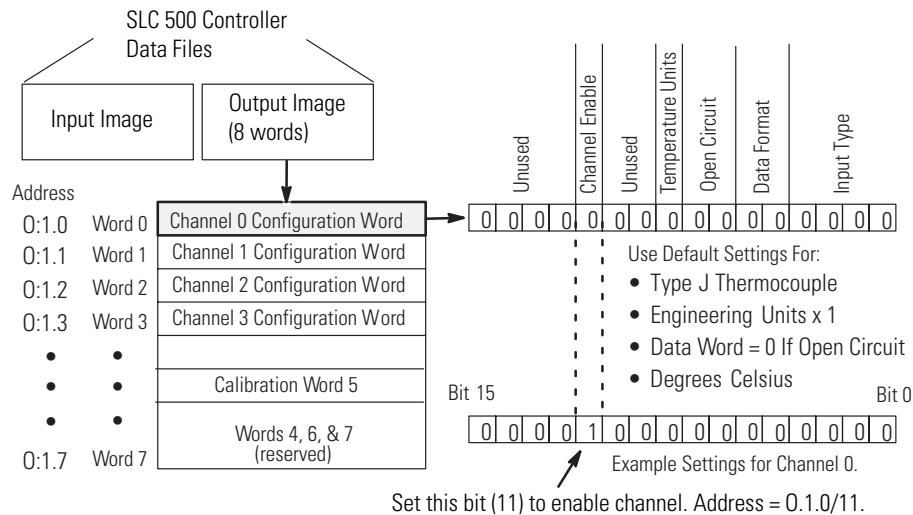


5. Configure the software to accept the module.

Type the module's ID and assigned slot (slot 1 in this example) into the system I/O configuration.

6. Set up Channel 0.

Determine the operating parameters for channel 0. This example shows the channel 0 configuration word defined with all defaults (0) except for the channel enable (bit 11=1). Module assumed in slot 1. (For details on channel configuration, refer to the configuration worksheet on page 22).



7. Program the transfer of the configuration word.

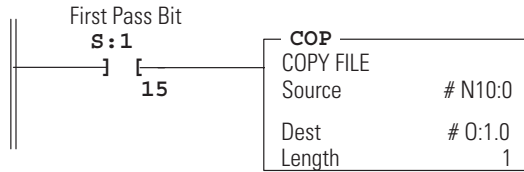
Program the transfer of the configuration word (from step 6) to the module.

- Using the memory map function, create integer file N10. Integer file N10 should contain one element for each channel used. (For this example, we used N10:0.).
- Enter configuration parameters for channel 0 (from step 6) into N10:0.
In this example, all of the bits of N10:0 are zero except for the channel enable bit (N10:0/11).
- Program a ladder logic instruction to copy the contents of N10:0 to output word O:1.0.

Data Table Display of Integer File N10:0

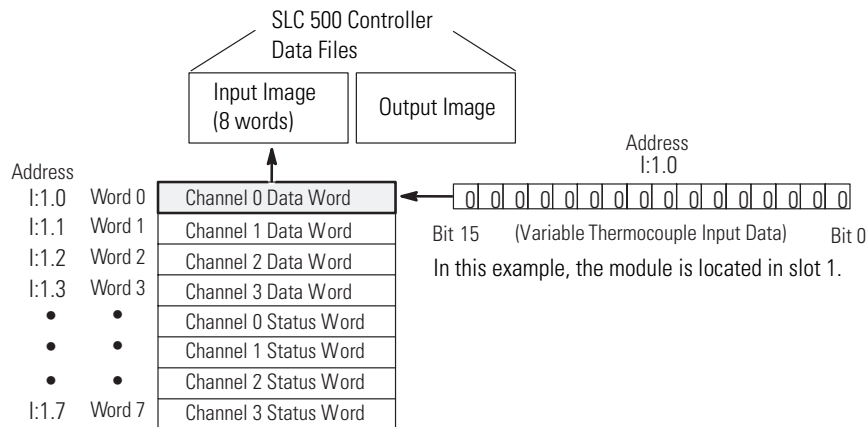
address	15	data	0	address	15	data	0
N10:0	0000	1000	0000	0000			

Ladder Logic to Transfer N10:0 to the Module:



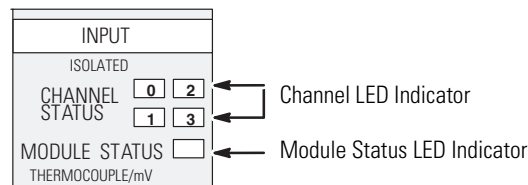
When cycling power, the first pass bit (S:1/15) is set for one scan, enabling the COPY instruction to transfer the configuration word to the processor's output image table. From there it is transferred to the module in the processor's I/O scan.

- Write ladder logic to process the thermocouple input data for your application.



- Apply power, download your program to the SLC processor and put the controller into Run mode.

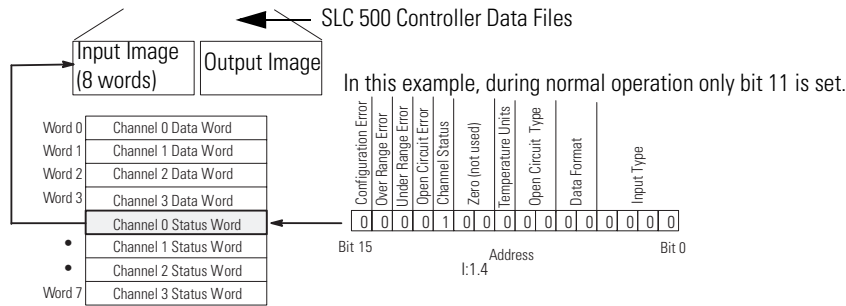
In this example, during a normal start up, the module status LED indicator and channel status 0 LED indicator turn on.



10. 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 been flagged.

If the Module Status LED indicator is off, or if the Channel 0 LED indicator is off or blinking, refer to Chapter 8.



Channel Configuration Worksheet

Select your bit configurations. Write them at the bottom of the worksheet. Use one worksheet for each channel.

Channel Configuration Word (0:e.0 ... 0:e.3) — Bit Descriptions

Bit or Bits	Define	To select	Set these bits in the Channel Configuration Word												Description	
			15...12	11	10	9	8	7	6	5	4	3	2	1		0
0...3	Input Type	TC Type J										0	0	0	0	Project _____ Slot Number _____ Channel Number _____ Configure the channel for the input type connected to it. Valid inputs are thermocouples and analog input signals of ±50 mV and ±100 mV. You can configure the channel to read the cold-junction (CJC) temperature. When reading the CJC temperature, the channel ignores the physical input signal.
		TC Type K										0	0	0	1	
		TC Type T										0	0	1	0	
		TC Type E										0	0	1	1	
		TC Type R										0	1	0	0	
		TC Type S										0	1	0	1	
		TC Type B										0	1	1	0	
		TC Type N										0	1	1	1	
		±50 mV										1	0	0	0	
		±100 mV										1	0	0	1	
		TC Type C										1	0	1	0	
		TC Type D										1	0	1	1	
		Invalid										1	1	0	0	
		Invalid										1	1	0	1	
		Invalid										1	1	1	0	
		CJC Temp										1	1	1	1	

Channel Configuration Word (0:e.0 ... 0:e.3) — Bit Descriptions (Continued)

Bit or Bits	Define	To select	Set these bits in the Channel Configuration Word														Description
			15...12	11	10	9	8	7	6	5	4	3	2	1	0		
4, 5	Data Format	Engr. Units x1								0	0					Select the channel data format from: Engineering units (EU) x1 or x10. For EU x1, values are in 0.1 ° or 0.01 mV. For EU x10, values are in whole °C or °F or 0.1 mV. Scaled-for-PID (value is the same for any input type). Proportional input signal range is scaled to 0...16,383 counts. Proportional counts (value is same for any input type). Proportional input signal range is scaled to ±32,767 counts. For more information, refer to page 49.	
		Engr. Units x10								0	1						
		Scaled-for-PID								1	0						
		Counts								1	1						
6, 7	Open-circuit Mode	Zero						0	0							Select module response to a detected open-circuit from: Zero to force the channel data word to zero. Upscale to force the channel data word to full scale. Downscale to force channel data word to low scale. Important: A bit selection or 1 1 is invalid. For an open CJC thermistor, mV channels are not affected. Important: The module requires 500 ms or one module update to flag the error while it ramps the channel input.	
		Upscale						0	1								
		Downscale						1	0								
		Invalid						1	1								
8	Units °F, °C	Degrees C				0										Select °C/°F for thermal inputs. Ignored for mV inputs. Important: For EU x1 and °F (0.1°F), an over-range error will occur above 3276.7 °F (cannot exceed 32767 counts).	
		Degrees F				1											
9, 10	Unused	Unused			0	0										These bits must be zero for a valid configuration.	
11	Chnl Enable	Channel Off		0												Disable unused channels for faster response. When set, the module configures the channel and reads the channel input before setting bit 11 in the status word. If you change the configuration word, the status word must reflect the change before new data is valid. If you clear the configuration word, the module clears channel and status words. For a new configuration word, channel data and status words remain cleared until the module sets this bit (11) in the status word.	
		Channel On		1													
12...15	Unused	Unused	0000													These bits must be zero for a valid configuration.	
Enter Your Bit Selections >>			0000													For the Channel Configuration Word	

Install and Wire the Module

This chapter tells you how to:

- avoid electrostatic damage.
- determine the module's chassis power requirement.
- install the module.
- wire signal cables to the module's terminal block.
- install the ferrite collar.

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.

- Touch a grounded object to rid yourself of charge before handling the module.
- Wear an approved wrist strap when 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.

Power Requirements

The module receives its power through the SLC 500 chassis backplane from the fixed or modular +5V dc/+24V dc chassis power supply. The maximum current drawn by the module is shown in this table.

Maximum Current

5V dc	24V dc
0.11 A	0.085 A

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

When using the module in a fixed controller, be sure not to exceed the power supply rating for the pair of modules in the two slot I/O chassis.

Fixed Controller Compatibility

Module	INT4	5V dc A	24V dc A
IA4	Yes	0.035	—
IA8	Yes	0.050	—
IA16	Yes	0.085	—
IM4	Yes	0.035	—
IM8	Yes	0.050	—
IM16	Yes	0.085	—
OA8	Yes	0.185	—
OA16	Yes	0.370	—
IB8	Yes	0.050	—
IB16	Yes	0.085	—
IV8	Yes	0.050	—
IV16	Yes	0.085	—
IG16	Yes	0.140	—
OV8	Yes	0.135	—
OV16	Yes	0.270	—
OB8	Yes	0.135	—
OG16	Yes	0.180	—
OW4	Yes	0.045	0.045
OW8	Yes	0.085	0.090
OW16		0.170	0.180
IO4	Yes	0.030	0.025
IO8	Yes	0.060	0.045
IO12	Yes	0.090	0.070
NI4	Yes	0.025	0.085
NI04I		0.055	0.145
NI04V		0.055	0.115
DCM		0.360	—
HS	Yes	0.300	—
OB16	Yes	0.280	—
IN16	Yes	0.085	—
INT4	Yes	0.110	0.085
BAS	Yes	0.150	0.040
OB32		0.452	—
OV32		0.452	—
IV32	Yes	0.106	—
IB32	Yes	0.106	—
OX8	Yes	0.085	0.090
NO4I		0.055	0.195
NO4V		0.055	0.145
ITB16	Yes	0.085	—
ITV16	Yes	0.085	—
KE	Yes	0.150	0.040
KE _n		0.150	0.145
OBP16	Yes	0.250	—
NT4	Yes	0.060	0.040
FIO4I		0.055	0.150
FIO4V		0.055	0.120

Considerations for a Modular System

Place your module in any slot of an SLC 500 modular, or modular expansion chassis, except for the leftmost slot (slot 0) reserved for the SLC processor or adapter modules.

Considerations for a Fixed Controller

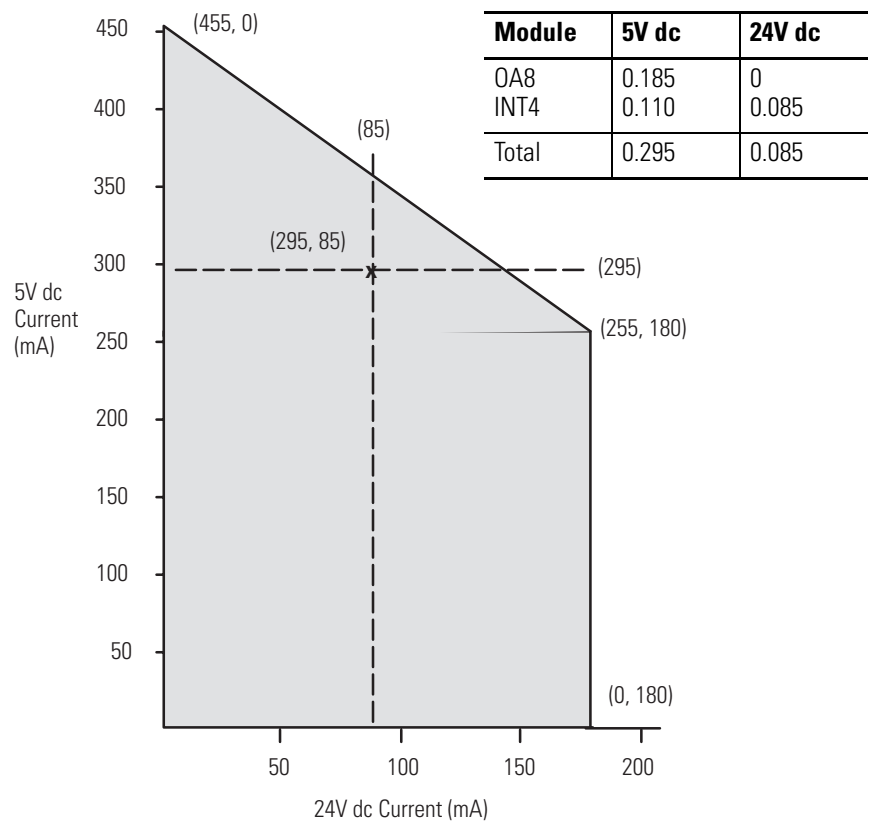
The power supply in the two slot SLC 500 fixed I/O chassis (1746-A2) can support only specific combinations of modules.

Refer to the table at the left or to the Chart Method below to determine whether the power supply can support the pair of modules.

Chart Method

Follow these steps to use the chart to determine a valid pair of modules.

1. For both modules, add the current rating at 5V dc and again at 24V dc.
2. On the chart, draw a horizontal line for the total 5V dc current rating.
3. On the chart, draw a vertical line for the total 24V dc current rating.
4. Observe the intersection; if within the chart boundary, the pair is OK.



IMPORTANT

Some analog I/O modules, such as the 1746-FIO4I, 1746-FIO4V, 1746-NO4I, and 1746-NO4V, may require an additional 24V dc power supply. For those modules, as needed, refer to the user manual.

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.

Write-on Label

SLOT _____ RACK _____

● MODULE _____

Terminal Block Removal

ATTENTION

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

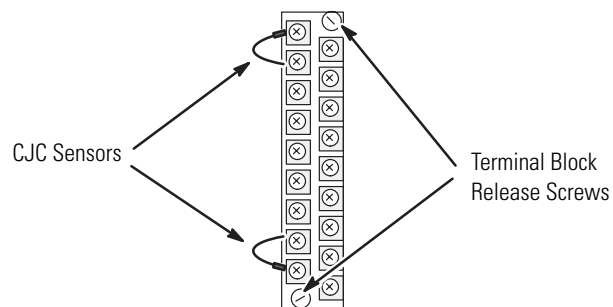
Follow these steps to remove the terminal block.

1. Loosen the two terminal-block release screws.

To avoid cracking the terminal block, alternate between screws as you remove them.

2. Grasp the terminal block at the top and bottom and pull outward and down.

When removing or installing the terminal block, be careful not to damage the CJC sensors.



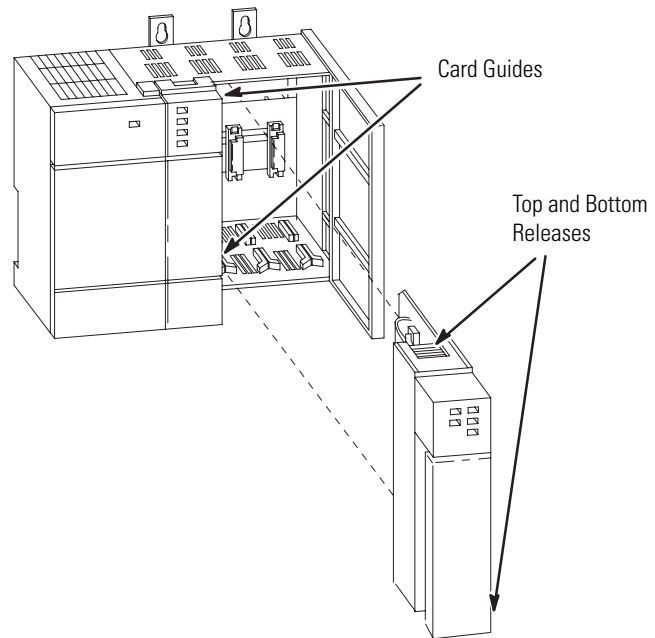
Module Installation Procedure

Follow these steps to install a module.

1. Align the circuit board of the thermocouple module with the card guides located at the top and bottom of the chassis.
2. 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.

3. Cover unused slots with the Card Slot Filler, catalog number 1746-N2.
4. To remove, press the releases at the top and bottom of the module, and slide the module out of the chassis slot.

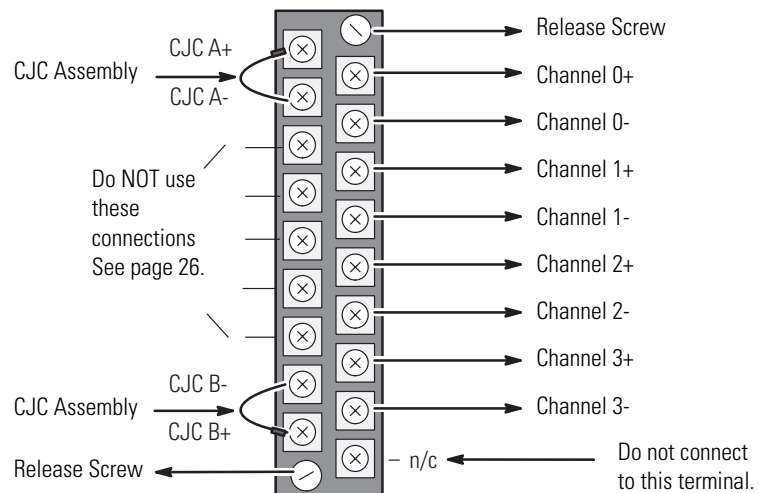


Wire the Module

The module contains a green, 18-position, removable terminal block.

Terminal Block

(Terminal Block Spare Part Catalog Number 1746-RT32)



ATTENTION



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

Cold-junction Compensation (CJC)

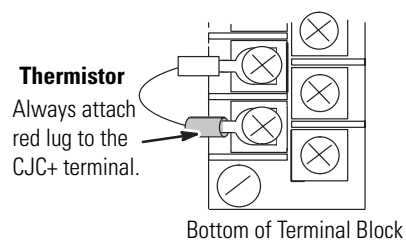
ATTENTION



Do not remove or loosen the cold-junction compensating thermistors located on the terminal block. Both thermistors are critical to be sure of accurate thermocouple input readings at each channel. The module does not operate in the thermocouple mode if a thermistor is removed.

In case of accidental removal of one or both thermistors, replace them by connecting them across the CJC terminals located at the top and/or bottom left side of the terminal block. Always connect the red lug to the (+) terminal (to CJC A+ or CJC B+).

CJC Connection



Wiring Considerations

Thermocouple inputs are highly susceptible to electrical noise due to the small signal amplitudes (microvolt/°C). Most applications require that the processor and I/O chassis be installed in an industrial enclosure to reduce the effects of electrical interference. Consider the following conditions when selecting a slot location for the module. Position the module away from other modules that:

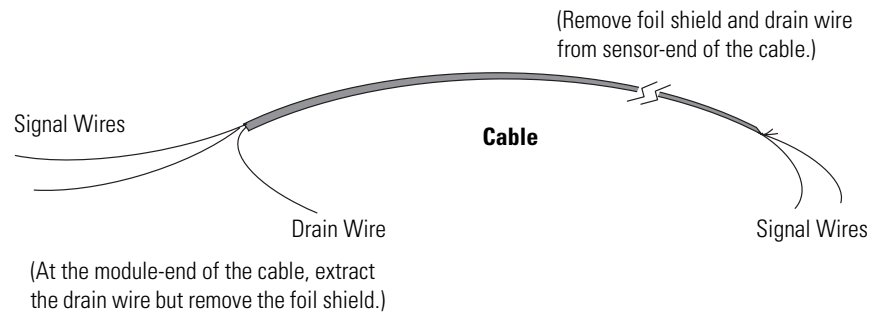
- connect to sources of electrical noise, such as relays and ac motor drives.
- generate significant heat, such as 32-point I/O modules.

Follow these guidelines to wire your input signal cables.

- To limit the pickup of electrical noise, keep thermocouple and millivolt signal wires as far from power and load lines as possible.
- For high immunity to electrical noise, use Alpha 5121 (shielded, twisted pair) or equivalent wire for millivolt sensors; or use shielded, twisted-pair thermocouple extension lead wire specified by the thermocouple manufacturer. Using the incorrect type of thermocouple extension wire or not following the correct polarity may cause invalid readings.
- Ground the shield drain wire at only one end of the cable. The preferred location is at the I/O chassis ground (see page 31). (Refer to IEEE Std. 518, Section 6.4.2.7, or contact your sensor manufacturer for additional details.)
- Keep all unshielded wires as short as possible.
- Tighten screw terminals with care. Excessive tightening can strip a screw.
- The open-circuit detector generates approximately 20 nano-amperes into the thermocouple cable. A total lead resistance of 25 ohms (12.5 one-way) will produce 0.5 microvolt of error.
- Follow system grounding and wiring guidelines found in your SLC 500 Installation and Operation Manual, publication 1747-UM011.

Prepare and Wire the Cables

Follow these steps to prepare and connect cable leads and drain wires.



1. At each end of the cable, strip some casing to expose individual wires.
2. Trim signal wires to 12.5 cm (5 in.) lengths beyond the cable casing and strip about 4.76 mm (3/16 in.) of insulation to expose the ends of the wires.

IMPORTANT

See the Cable Preparation and Connections to Minimize Electrical Noise Interference illustration on page 33 for more information about the cables.

3. At the module-end of the cables:
 - extract the drain wire and signal wires.
 - remove the foil shield.
 - bundle the input cables with a cable strap.
4. Connect drain wires together and solder them to a 9.5 mm (3/8 in.) wire braid, 30.5 cm (12 in.) long, keeping drain wires as short as possible.
5. Connect the 9.5 mm (3/8 in.) wire braid to the nearest chassis mounting bolt.
6. Connect the signal wires of each channel to the terminal block.

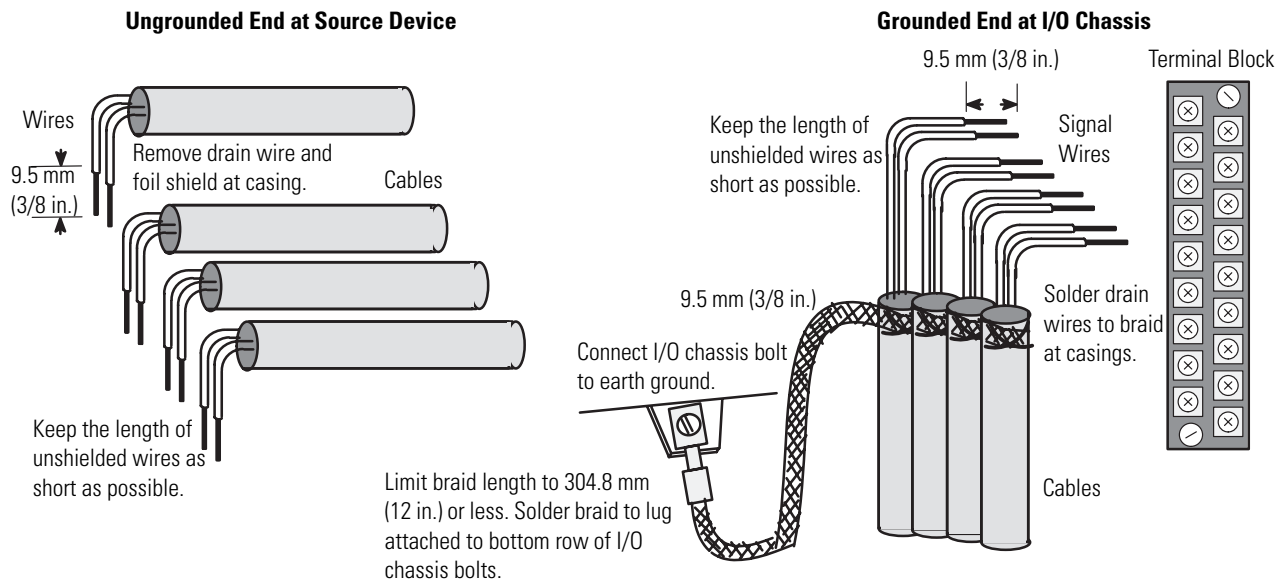
IMPORTANT

Only after verifying that your connections are correct for each channel, trim the lengths to keep them short. Avoid cutting leads too short.

7. At the source-end of cables from mV devices:
 - remove the drain wire and foil shield.
 - apply shrink wrap as an option.
 - connect to mV devices keeping the leads short.

IMPORTANT

If noise persists, try grounding the opposite end of the cable, instead. (Ground one end only.)

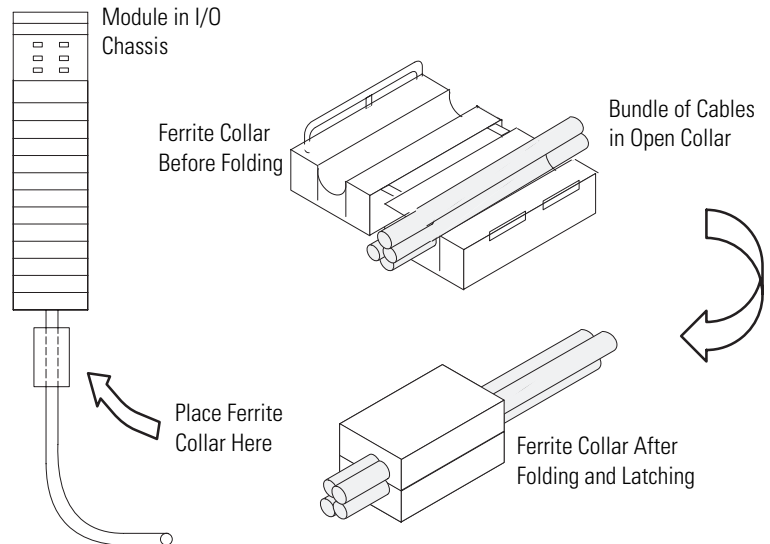
Cable Preparation and Connections to Minimize Electrical Noise Interference

Install the Ferrite Collar

For immunity to electrical noise with this CE-marked module, insert a ferrite collar (Fair-Rite Inc. part number 0443164151) around the input cables immediately beneath the module in the I/O chassis.

Follow these steps to install the ferrite collar.

1. Bundle the cables at the module end.
2. Fold the collar so that it encircles the cables.
3. Press the plastic housing until the collar snaps together.
4. Check that the collar is fully latched.
5. If the collar slides on the cables, use a cable tie to secure it.



Ferrite Collar

Part Number: 0443164151

Fair-Rite Inc.
P.O. Box J
1 Commercial Rd.
Wallkill, NY 12589
(914) 895-2055

Preliminary Operating Considerations

This chapter explains how the module and the SLC processor communicate through the processor's I/O image tables. It also describes the module's input filter characteristics. Topics discussed include:

- module ID code.
- module addressing.
- input channel characteristics.
- response to slot disabling.

Module ID Code

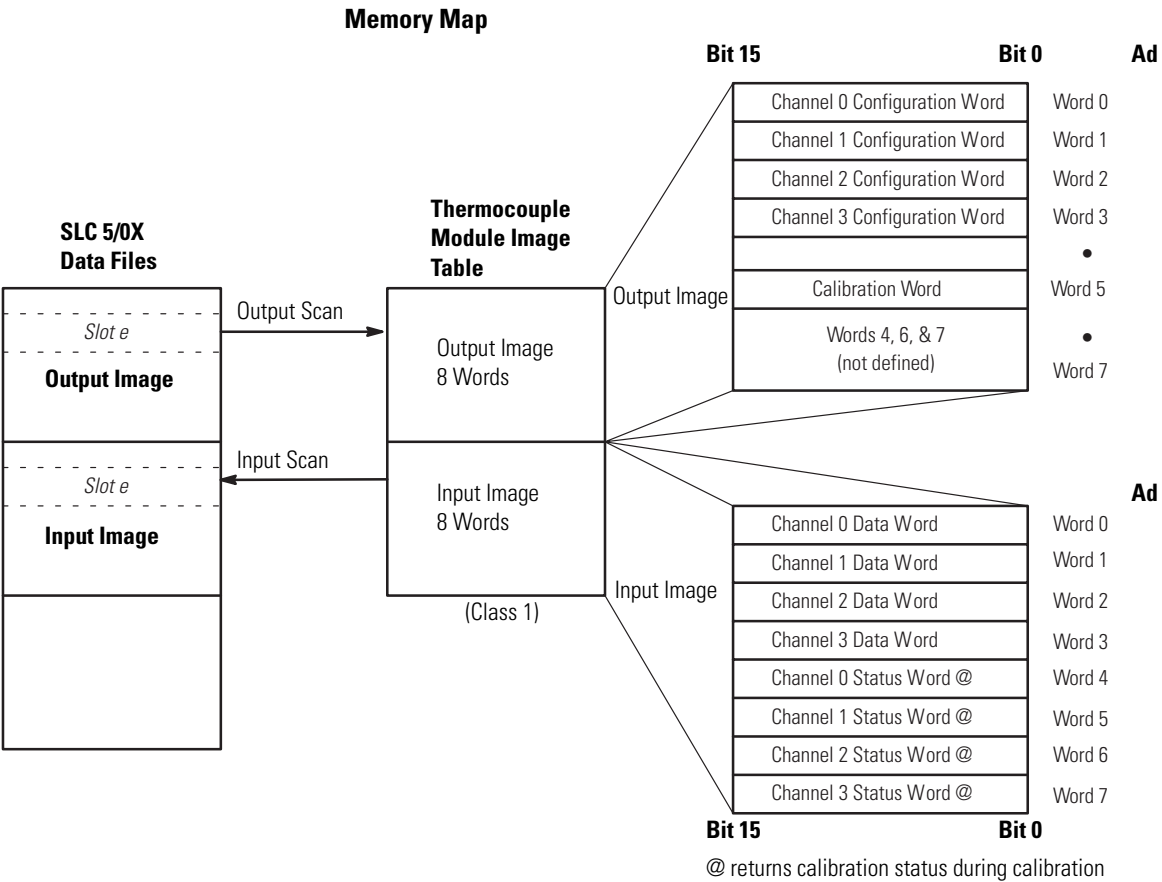
The module ID code is a unique number assigned to each type of 1746 I/O module. The ID defines for the processor the type of I/O module and the number of words used in the processor's I/O image table.

Use the system I/O configuration display to select the 1746-INT4 module or manually enter the module ID. Do this by selecting Other from the list of modules on the system I/O configuration display and enter 3515, the ID code for the 1746-INT4 module.

No special I/O configuration is required. The module ID automatically assigns the correct number of input and output words.

Module Addressing

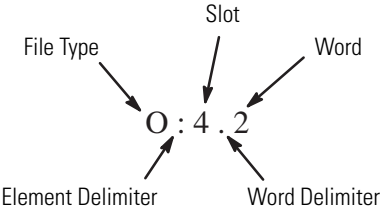
The following memory map shows you how the SLC processor's output and input image tables are defined for the module.



Output Image — Configuration Words

Eight words of the SLC processor's output image table are reserved for the module. Output image words 0...3 are used to configure the module's input channels 0...3. Each output image word configures a single channel, and is referred to as a configuration word. Word 5 is used for calibration. Each word has a unique address based on the slot number assigned to the module. (The remaining three words are not used.)

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



Chapter 6, Channel Configuration, Data, and Status, gives you detailed bit information about the data content of the configuration word.

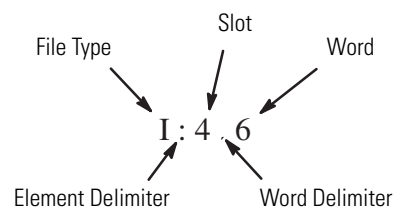
Input Image — Data Words and Status Words

Eight words of the SLC processor's input image table are reserved for the module. Input image words 0...3 (data words) hold the temperature values of thermocouple analog inputs for channels 0...3. The data is valid only when the channel is enabled, no errors are detected, and not during calibration.

Input words 4...7 (status words) contain the status of channels 0...3. Status bits for a particular channel reflect the configuration settings that you entered into the configuration (output image) word for that channel. To receive valid status, the channel must be enabled and the module must have stored a valid configuration word for that channel. During calibration, these words return calibration status.

Each input image word has a unique address based on the slot number assigned to the module.

Example Address — To obtain the status of channel 2 (input word 6) of the module located in slot 4 in the SLC chassis, use address I:4.6.



Chapter 6, Channel Configuration, Data, and Status, gives you detailed bit information about the content of the data word and the status word.

Input Channel Characteristics

Each channel has an 8 Hz digital filter for input noise rejection, a multiplexer for processing cold junction compensation (CJC) values, and an analog-to-digital (A/D) converter to provide digital values for SLC processing.

Channel Cut-off Frequency, Update Time, and Step Response

The channel cut-off frequency is defined as the point on the frequency response curve where frequency components of the input signal are passed with 3 dB of attenuation by the input filter. All frequency components above cut-off frequency are increasingly attenuated. Cut-off frequency is also defined as the Normal Mode Rejection (NMR) in dB of attenuation at 50 Hz (European) or at 60 Hz (American).

See the Cut-off Frequencies graph on page 39.

We define module update time as the time required for the module to sample and convert channel input signals, multiplex them with the CJC reference value, and make the resulting values available to the SLC processor. It is typically 200 ms for multiplexing and 200 ms for sampling and converting.

When sampling occurs after the signal reaches 99.9% of final value, the update time defines the minimum time (400 ms) for processing an input signal.

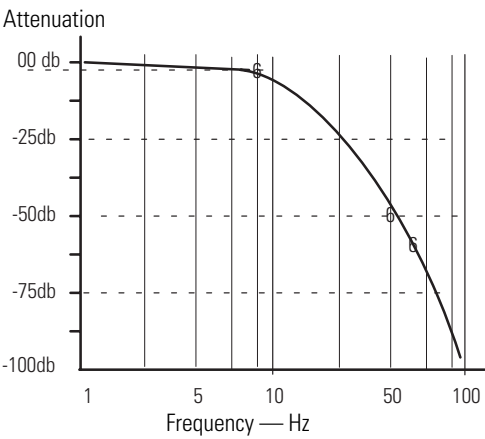
When sampling occurs just before the signal reaches 99.9% of final value, we define step response (worst-case) as the sum of the times required for the analog input signal to change from 0...99.9% of its expected final value (see graph). It includes the times required for:

- input filter: 180 ms.
- CJC multiplexer: 200 ms.
- A/D converter: 200 ms.

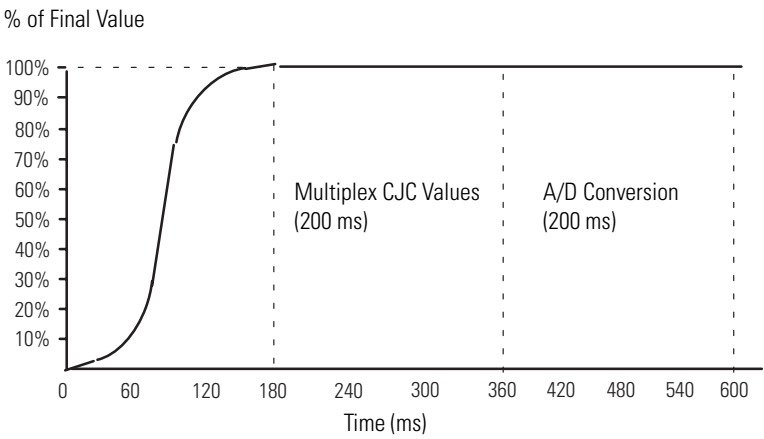
This defines the maximum time required for processing an input signal.

Cut-off Frequencies

Frequency Response of the 8 Hz Filter Converter



Step Response (worst case) for Filter, Multiplexer, and A/D



The following table summarizes the input channel characteristics:

Input Channel Characteristics

Corner Frequency	50/60 Hz NMR	Filter Time	Update Time	Step Response (worst)
8 Hz	50 ... 60 dB	180 ms	400 ms	600 ms

Effective Resolution of a Channel and Input Device

The effective resolution of an input channel depends upon the type of input device connected to it.

For thermocouples, we define resolution as the smallest increment of temperature that can be sampled after A/D conversion. It varies with temperature and with the type of thermocouple.

We present a resolution graph for each type of thermocouple in Appendix A, Module Specifications.

Millivolt devices are generally considered linear, and the effective resolution is that of the channel itself.

Millivolt Devices

Type of Device	Resolution
Thermocouple	0.05...0.75 °C @ 300 °C (32.1...33.4 °F @ 572 °F) depending on the thermocouple
Millivolt Sensor	3.4 µV/bit

Response to Slot Disabling

By writing to the status file in your modular SLC processor you can disable any chassis slot.

Refer to your SLC programming manual for the slot disable/enable procedure.

ATTENTION

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

Input Response

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

Output Response

When the slot for this module is disabled, configuration words in the SLC processor's output image table are held in their last state and not transferred to the module. When the slot is re-enabled, output image table words are transferred to the module during the subsequent scan.

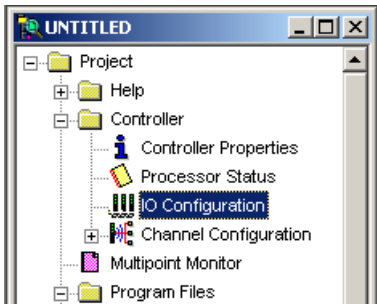
Access Files to Configure I/O

There are two ways to configure the SLC chassis for a 1746-INT4 module. You can either click and drag items from the list or you can use the Read IO Config method.

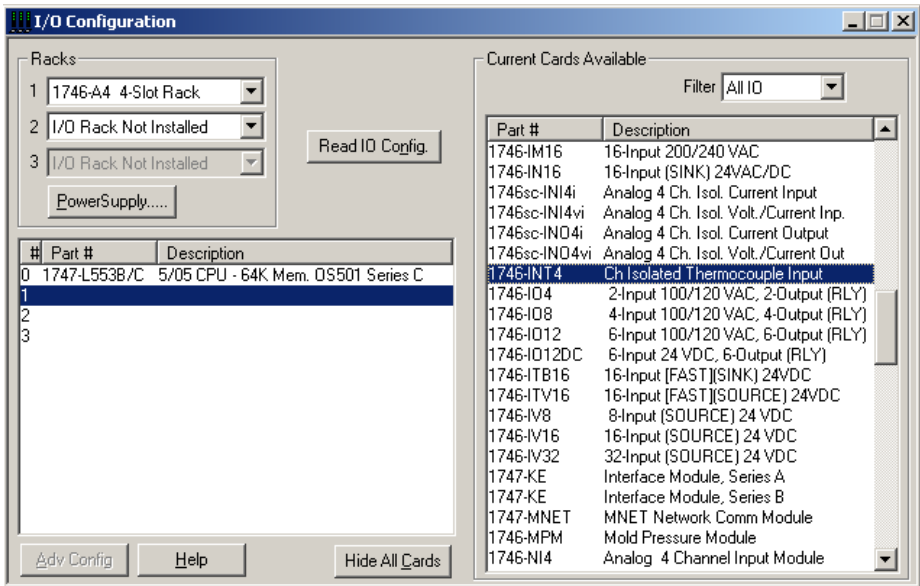
Click and Drag Configuration

Follow these steps to configure the SLC chassis by clicking and dragging modules.

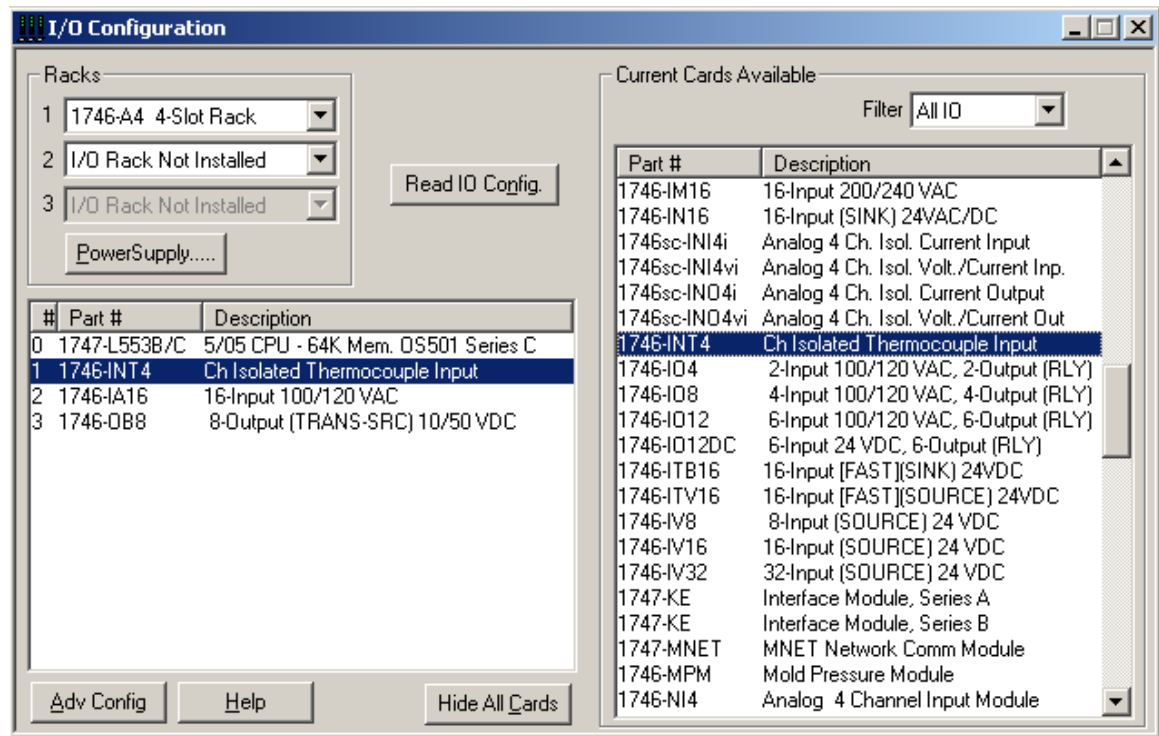
- 1. Double-click the menu item to open the IO Configuration menu in the RSLogix 500 software.



- 2. Place the 1746-INT4 module into the correct slot by clicking and dragging from the list.



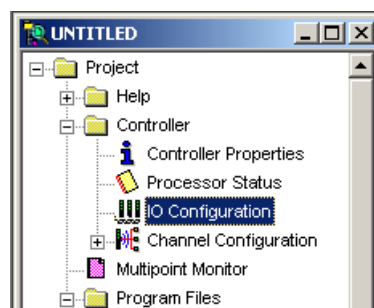
The I/O Configuration is now complete. Each slot shows the corresponding module that is located on the rack. In this example, 1746-INT4 is in slot 1.



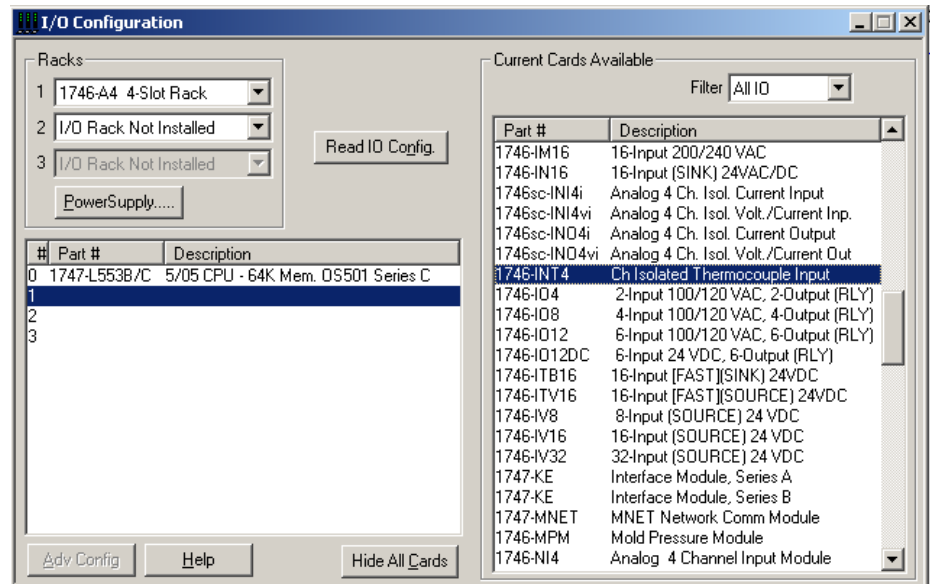
Read IO Config Method

Follow these steps to configure the SLC chassis by using the read I/O configuration method.

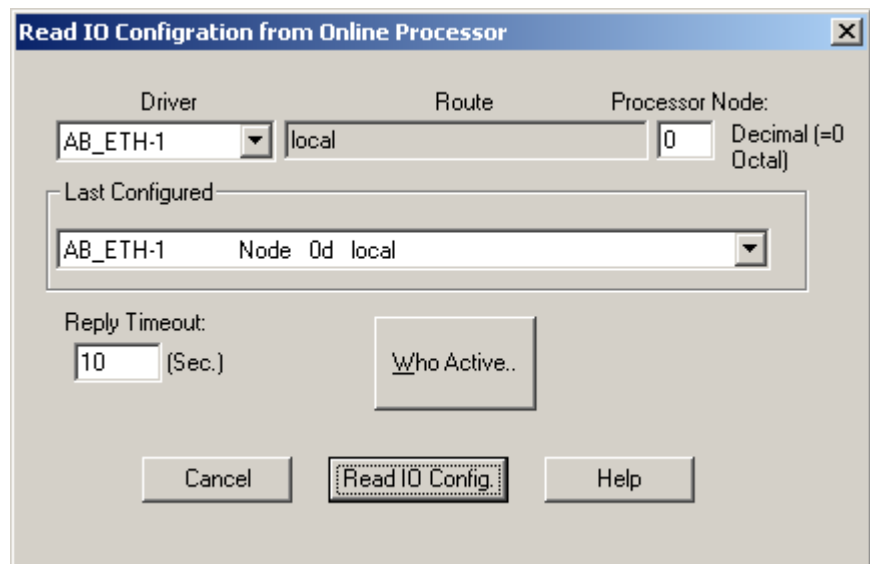
1. Double-click the menu item to open the IO Configuration menu in the RSLogix 500 software.



- Place the 1746-INT4 module into the correct slot by clicking Read IO Config.

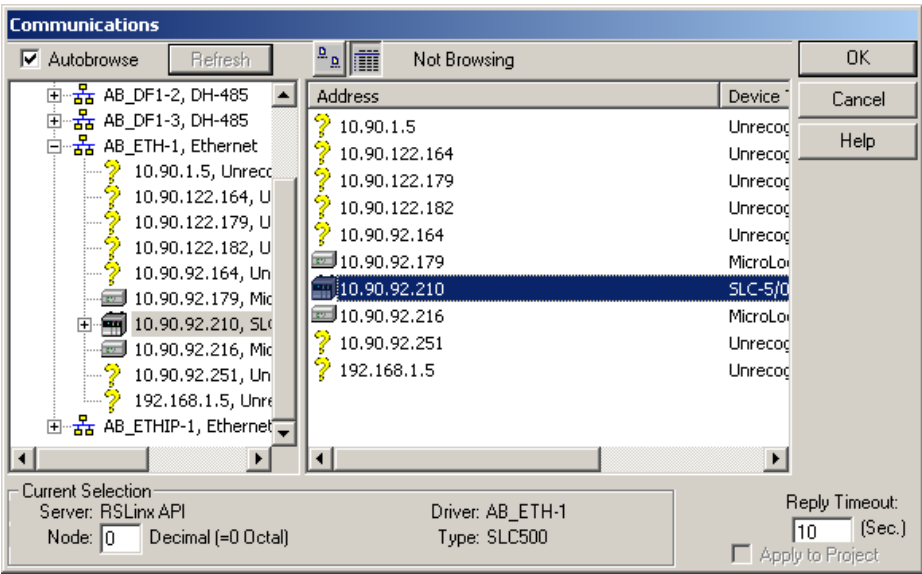


The following screen appears.



- Select either the driver and processor node number or click Who Active to browse for the device.
 - If you selected the driver and node number, proceed to step 5.
 - If you clicked Who Active, the following screen appears.

The Who Active screen lets you to browse for the SLC device.

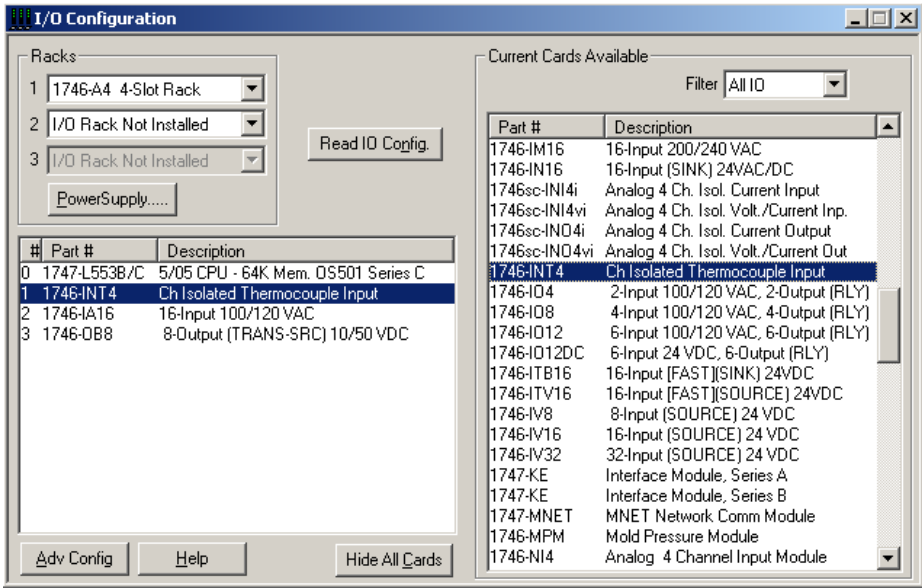


4. Locate the SLC chassis under the appropriate driver and click OK.

You return to the Read IO Config dialog.

5. Click Read IO Config and the rack is populated automatically.

The I/O Configuration is now complete. Each slot shows the corresponding module that is located on the rack. In this example, the 1746-INT4 is in slot 1.



Channel Configuration, Data, and Status

This chapter examines channel configuration and status words, and explains how you use them. It gives you information about how to:

- configure a channel.
- check a channel's status.

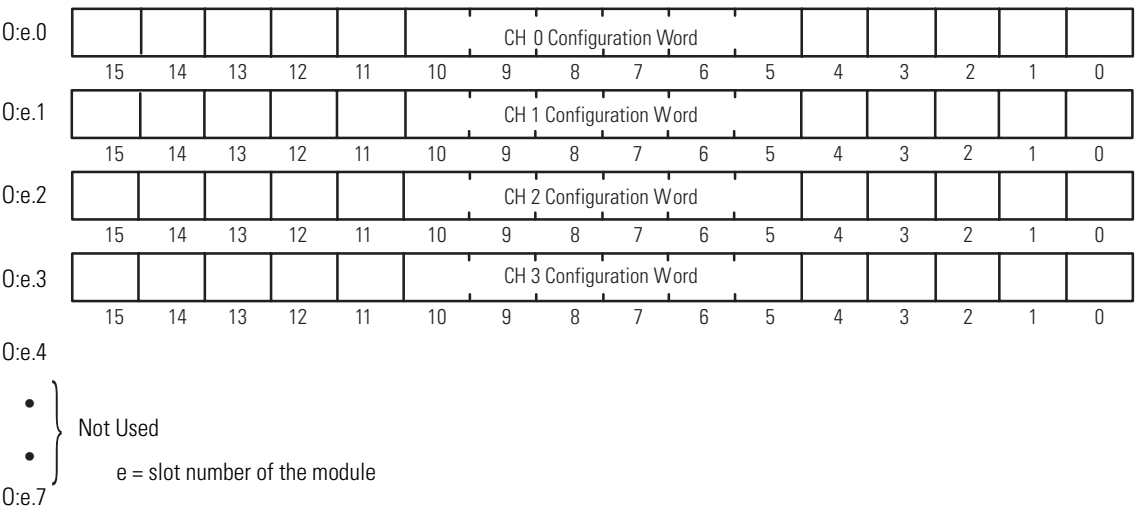
Channel Configuration

Channel configuration words appear in the SLC controller's output image table as shown below. Words 0...3 correspond to module channels 0...3. Words 4...7 are not used.

After module installation, you must configure each channel to establish the way the channel operates (for example, thermocouple type and temperature units). You configure the channel by setting bits in the configuration word using your programmer. We present bit descriptions next.

For information on addressing, using your software and programming, refer to Chapters 4, 5, and 7, respectively.

SLC Output Image (Configuration) Words



The configuration word default settings are all zero. Next, we describe how you set configuration bits of a channel configuration word to set up the following channel parameters:

- Type of thermocouple or mV input
- Data format, such as engineering units, counts, or scaled for PID
- How the channel should respond to a detected open input circuit
- Temperature units in °C or °F
- Whether the channel is enabled or disabled

Channel Configuration Word (0:e.0 through 0:e.3) — Bit Descriptions

Bit or Bits	Define	To Select	Set these bits in the Channel Configuration Word														Description
			15...12	11	10	9	8	7	6	5	4	3	2	1	0		
0...3	Input Type	TC Type J										0	0	0	0	Configure the channel for the input type connected to it. Valid inputs are thermocouples and analog input signals of ±50 mV and ±100 mV. You can configure the channel to read the cold-junction (CJC) temperature. When reading the CJC temperature, the channel ignores the physical input signal.	
		TC Type K										0	0	0	1		
		TC Type T										0	0	1	0		
		TC Type E										0	0	1	1		
		TC Type R										0	1	0	0		
		TC Type S										0	1	0	1		
		TC Type B										0	1	1	0		
		TC Type N										0	1	1	1		
		±50 mV										1	0	0	0		
		±100 mV										1	0	0	1		
		TC Type C										1	0	1	0		
		TC Type D										1	0	1	1		
		Invalid										1	1	0	0		
		Invalid										1	1	0	1		
		Invalid										1	1	1	0		
		CJC Temp										1	1	1	1		
4, 5	Data Format	Engr. Units x1								0	0					Select the channel data format from: Engineering units (EU) x1 or x10. For EU x1, values are in 0.1 degrees or 0.01 mV. For EU x10, values are in whole °C or °F or 0.1 mV. Scaled-for-PID (value is the same for any input type). Proportional input signal range is scaled to 0...16,383 counts. Proportional counts (value is same for any input type). Proportional input signal range is scaled to ±32,767 counts. For more information, refer to page 49.	
		Engr. Units x10								0	1						
		Scaled-for-PID								1	0						
		Counts								1	1						
6, 7	Open-circuit Mode	Zero						0	0							Select module response to a detected open-circuit from: Zero to force the channel data word to zero. Upscale to force the channel data word to full scale. Downscale to force channel data word to low scale. Important: A bit selection or 1 1 is invalid. For an open CJC thermistor, mV channels are not affected. Important: The module requires 500 ms or one module update to flag the error while it ramps the channel input.	
		Upscale						0	1								
		Downscale						1	0								
		Invalid						1	1								
8	Units °F, °C	Degrees C				0										Select °C/°F for thermal inputs. Ignored for mV inputs. Important: For EU x1 and °F (0.1 °F), an over-range error occurs above 3276.7 °F (cannot exceed 32767 counts).	
		Degrees F				1											

Channel Configuration Word (0:e.0 through 0:e.3) — Bit Descriptions (Continued)

Bit or Bits	Define	To Select	Set these bits in the Channel Configuration Word													Description
			15...12	11	10	9	8	7	6	5	4	3	2	1	0	
9, 10	Unused	Unused			0	0										These bits must be zero for a valid configuration.
11	Chnl Enable	Channel Off		0												Disable unused channels for faster response. When set, the module configures the channel and reads the channel input before setting bit 11 in the status word. If you change the configuration word, the status word must reflect the change before new data is valid. If you clear the configuration word, the module clears channel and status words. For a new configuration word, channel data and status words remain cleared until the module sets this bit (11) in the status word.
		Channel On		1												
12...15	Unused	Unused	0000													These bits must be zero for a valid configuration.
Enter Your Bit Selections >>			0000													Selected Configuration Word

Select the Correct Data Format

To provide the highest display resolution, select Scaled-for-PID or Proportional Counts. To use either one, you may have to convert channel data to/from Engineering Units, manually or logically.

The following examples show you how to do this.

Use Scaled-for-PID and Proportional Counts

You must obtain the minimum (S_{LOW}) and maximum (S_{HIGH}) values of the temperature or millivolt range for the channel's input type, and use them in your computations.

We present these values in the section Using Channel Data Words on page 51, in the table Format of a Channel Data Word.

Scaling Examples: Convert Between Units

Convert from Scaled-for-PID to Equivalent Engineering Units in °C

Equation: Engr Units Equivalent = $S_{LOW} + [(S_{HIGH} - S_{LOW}) \times (\text{Scaled-for-PID value displayed} / 16,384)]$
 Assume type J input type, scaled-for-PID, channel data = 3421.
 From Channel Data Word Format table, $S_{LOW} = -210\text{ °C}$ and $S_{HIGH} = 760\text{ °C}$.

Solution: Engr Units Equivalent = $-210\text{ °C} + [(760\text{ °C} - (-210\text{ °C})) \times (3421 / 16,384)] = -7.46\text{ °C}$

Convert from Engineering Units in °C to Equivalent Scaled-for-PID Count

Equation: Scaled-for-PID Equivalent = $16,384 \times [(\text{Engineering Units desired} - S_{LOW}) / (S_{HIGH} - S_{LOW})]$
 Assume type J input type, scaled-for-PID, desired channel temp. = 344 °C .
 From Channel Data Word Format table, $S_{LOW} = -210\text{ °C}$ and $S_{HIGH} = 760\text{ °C}$.

Solution: Scaled-for-PID Equivalent = $16,384 \times [(344\text{ °C} - (-210\text{ °C})) / (760\text{ °C} - (-210\text{ °C}))] = 9357$.

Convert from Proportional Counts to Equivalent Engineering Units in °F

Equation: Engr Units Equivalent = $S_{LOW} + [(S_{HIGH} - S_{LOW}) \times ((\text{Proportional Counts value displayed} + 32,768) / 65,536)]$
 Assume type E input type, proportional counts, channel data = 21,567 counts.
 From Channel Data Word Format table, $S_{LOW} = -454\text{ °F}$ and $S_{HIGH} = 1832\text{ °F}$.

Solution: Engr Units Equivalent = $-454\text{ °F} + [(1832\text{ °F} - (-454\text{ °F})) \times ((21,567 + 32,768) / 65,536)] = 1441.3\text{ °F}$

Convert from Engineering Units in °F to Equivalent Proportional Counts

Equation: Proportional Counts Equivalent = $\{65,536 \times [(\text{Engineering Units desired} - S_{LOW}) / (S_{HIGH} - S_{LOW})]\} - 32,768$
 Assume type E input type, proportional counts, desired channel temp. = 1000 °F .
 From Channel Data Word Format table, $S_{LOW} = -454\text{ °F}$ and $S_{HIGH} = 1832\text{ °F}$.

Solution: Proportional Counts Equivalent = $\{65,536 \times [(1000\text{ °F} - (-454\text{ °F})) / (1832\text{ °F} - (-454\text{ °F}))]\} - 32,768 = 8916\text{ counts}$.

Channel Configuration Procedure

Use this procedure once for each channel to set configuration bits that determine channel operation. Copy it as needed to write down configuration selections of all your channels.

Use the table of bit descriptions and the blank configuration worksheet in Appendix B.

1. Determine the input device type (thermocouple or mV) for a channel and enter its respective four digit binary code in bit field 0...3.

2. Select the data format for the data word.

Your selection determines how the analog input from the A/D converter is expressed in the data word.

3. Enter your two digit binary code in bit field 4...5.

4. Determine the desired change to the channel data word when the module detects an open input circuit.

Enter the two digit binary code in bit field 6...7.

5. If the channel is configured for thermocouple inputs, determine if you want channel data in degrees Fahrenheit or Celsius, and set bit 8 accordingly.

IMPORTANT

If the channel is configured for a mV analog sensor, set bit 8 to 0.

6. Enable the channel by setting bit 11.

Default disables the channel.

7. Verify that bits 9, 10, and 12...15 are zero.

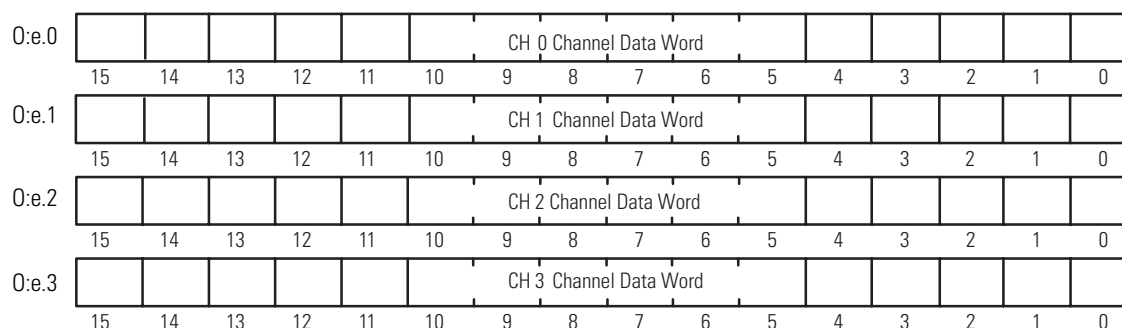
8. Repeat steps 1...7 for each channel used.

9. After entering your ladder logic to transfer data to the module, switch the SLC controller to Run mode to download channel configurations.

Use Channel Data Words

Thermocouple or millivolt input data reside in I:e.0 to I:e.3 of the SLC controller's input image file (where e is the slot number assigned to the module). The values depend on the input type and data format that you select. When an input channel is disabled, its data word is reset (0).

SLC Controller's Input Image File (Data Word)



Format of a Channel Data Word

Input Type	Data Format					
	Engineering Units x 10		Engineering Units x 1		Scaled-for-PID	Proportional Counts
	° Celsius	° Fahrenheit	° Celsius	° Fahrenheit		
C	0...2317	32...4201	0...23,170	320...32,767	0...16,383	-32,768...32,767
D	0...2317	32...4201	0...23,170	320...32,767	0...16,383	-32,768...32,767
J	-210...760	-346...1400	-2100...7600	-3460...14,000	0...16,383	-32,768...32,767
K	-270...1370	-454...2498	-2700...13,700	-4540...24,980	0...16,383	-32,768...32,767
T	-270...400	-454...752	-2700...4000	-4540...7520	0...16,383	-32,768...32,767
E	-270...1000	-454...1832	-2700...10,000	-4540...18,320	0...16,383	-32,768...32,767
R	0...1768	32...3214	0...17,680	320...32,140	0...16,383	-32,768...32,767
S	0...1768	32...3214	0...17,680	320...32,140	0...16,383	-32,768...32,767
B	300...1820	572...3308	3000...18,200	5720...32,767 ⁽²⁾	0...16,383	-32,768...32,767
N	0...1300	32...2372	0...13,000	320...23720	0...16,383	-32,768...32,767
±50 mV	-50...50 ⁽¹⁾	-50...50 ⁽¹⁾	-500...500 ⁽¹⁾	-500...500 ⁽¹⁾	0...16,383	-32,768...32,767
±100 mV	-1000...1000 ⁽¹⁾	-1000...1000 ⁽¹⁾	-10000...10,000 ⁽¹⁾	-10000...10,000 ⁽¹⁾	0...16,383	-32,768...32,767
CJC Sensor	0...85	32...185	0...850	32...1850	0...16,383	-32,768...32,767

⁽¹⁾ When millivolts are selected, the temperature setting is ignored. Analog input data is the same for either °C or °F selection.

⁽²⁾ Type B, C, and D thermocouples cannot be represented in engineering units x 1 (°F) above 3276.7 °F. Software treats it as an over-range error.

Resolution of a Channel Data Word

Input Type	Data Format							
	Engineering Units x 10		Engineering Units x 1		Scaled-for-PID		Proportional Counts	
	° Celsius	° Fahrenheit	° Celsius	° Fahrenheit	° Celsius	° Fahrenheit	° Celsius	° Fahrenheit
C	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.1414 °C/step	0.2564 °C/step	0.0353 °C/step	0.0641 °C/step
D	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.1414 °C/step	0.2564 °C/step	0.0353 °C/step	0.0641 °C/step
J	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.0592 °C/step	0.1066 °F/step	0.0148 °C/step	0.0266 °F/step
K	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.1001 °C/step	0.1802 °F/step	0.025 °C/step	0.0450 °F/step
T	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.0409 °C/step	0.0736 °F/step	0.0102 °C/step	0.0184 °F/step
E	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.0775 °C/step	0.1395 °F/step	0.0194 °C/step	0.0349 °F/step
R	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.1079 °C/step	0.1942 °F/step	0.0270 °C/step	0.0486 °F/step
S	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.1079 °C/step	0.1942 °F/step	0.0270 °C/step	0.0486 °F/step
B	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.0928 °C/step	0.1670 °F/step	0.0232 °C/step	0.0417 °F/step
N	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.0793 °C/step	0.1428 °F/step	0.0198 °C/step	0.0357 °F/step
±50 mV ⁽¹⁾	0.1 mV/step	0.1 mV/step	0.01 mV/step	0.01 mV/step	6.104 µV/step	6.104 µV/step	3.40 µV/step	3.40 µV/step
±100 mV ⁽¹⁾	0.1 mV/step	0.1 mV/step	0.01 mV/step	0.01 mV/step	13.6 µV/step	13.6 µV/step	3.40 µV/step	3.40 µV/step
CJC Sensor	1 °C/step	1 °F/step	0.1 °C/step	0.1 °F/step	0.0052 °C/step	0.0093 °F/step	0.0013 °C/step	0.0023 °F/step

⁽¹⁾ When millivolts are selected, the temperature setting is ignored. Analog input data is the same for either °C or °F selection.

Use Channel Status Words

Channel status words are stored in the SLC controller's input image file at addresses I:e.4 to I:e.7 (where e is the slot number assigned to the module). Status words 4...7 correspond to and reflect the configuration of channels 0...3 (O:e.0...O:e.3).

Whenever a channel is disabled ($O:e.x/11 = 0$), its corresponding status word is zero. This condition tells you that input data contained in the channel data word is invalid and should be ignored.

IMPORTANT

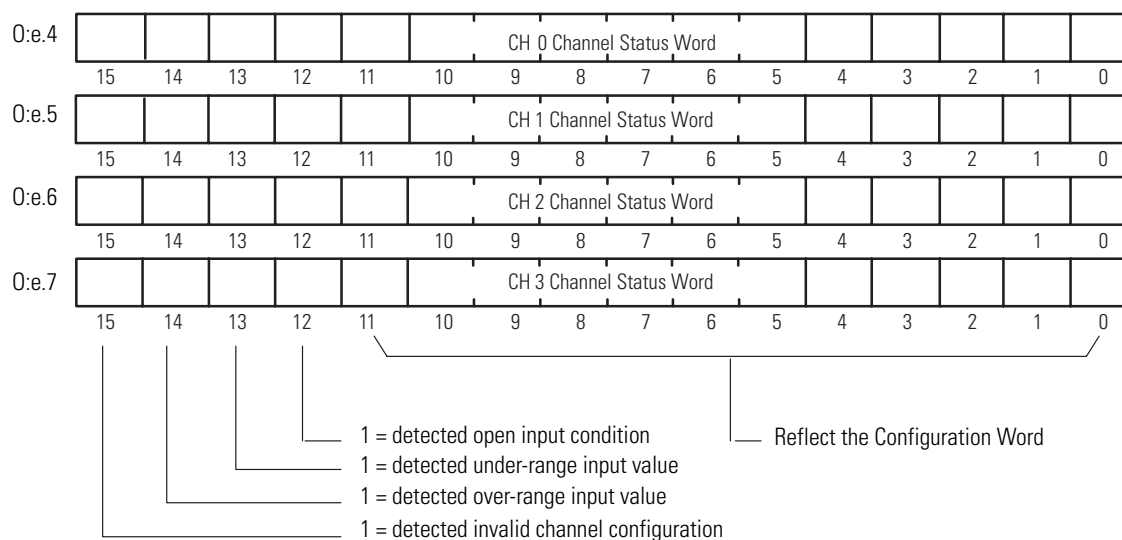
The status word from a disabled channel is always zero.

The status word of an enabled channel indicates the following status:

- Bits 0...10 reflect the channel configuration
- Bit 11 indicates whether the channel is enabled or disabled (configuration)
- Bits 12...15 indicate detected faults should they occur

We present status words as they appear in the input image table at I:e.4...I:e.7.

Module Input Image (Status Words)



Channel Status Word, Channels 0...3 (I:e.4 through I:e.7) — Bit Definitions

Bit or Bits	Reflect/ Indicate	Configured for	With This Bit Code															Reflects Configuration in Bits 0...11 and Indicates Detected Faults in Bits 12...15	
			15	14	13	12	11	10	9	8	7	6	5	4	3	2	1		0
0 ... 3	Input Type	TC Type J													0	0	0	0	Reflects the type of channel input.
		TC Type K													0	0	0	1	
		TC Type T													0	0	1	0	
		TC Type E													0	0	1	1	
		TC Type R													0	1	0	0	
		TC Type S													0	1	0	1	
		TC Type B													0	1	1	0	
		TC Type N													0	1	1	1	
		±50 mV													1	0	0	0	
		±100 mV													1	0	0	1	
		TC Type C													1	0	1	0	
		TC Type D													1	0	1	1	
		Invalid													1	1	0	0	
		Invalid													1	1	0	1	
		Invalid													1	1	1	0	
		CJC Temp													1	1	1	1	
4, 5	Data Format	Engr. Units x1											0	0				Reflects the type of data format.	
		Engr. Units x10											0	1					
		Scaled-for-PID											1	0					
		Counts											1	1					
6, 7	Open Input Mode	Zero									0	0						Reflects module response to a detected open input circuit (for all input types including CJC thermistor). The module faults when it detects an invalid configuration.	
		Upscale									0	1							
		Downscale									1	0							
		Invalid									1	1							
8	Units °F, °C	Degrees C								0								Reflects temperature units.	
		Degrees F								1									
9, 10	Unused	Unused						0	0									Faults when it detects a non-zero value.	
11	Chnl Enable	Channel Off					0											Reflects enabled/disabled channel status. Status word of a disabled channel is zero. Channel data and status words remain cleared until the module sets this bit in response to a new configuration word.	
		Channel On					1												

Channel Status Word, Channels 0...3 (I:e.4 through I:e.7) — Bit Definitions (Continued)

Bit or Bits	Reflect/Indicate	Configured for	With This Bit Code																Reflects Configuration in Bits 0...11 and Indicates Detected Faults in Bits 12...15
			15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
12	Open Input	Diagnostics				0													Condition not detected.
						1													Detected open input.
13	Under-range	Diagnostics			0														Condition not detected.
					1														Detected under-range input.
14	Over-range	Diagnostics		0															Condition not detected.
				1															Detected over-range input.
15	Invalid Config	Diagnostics	0																Condition not detected.
			1																Detected invalid configuration.

Detected Faults Indicated by Bits 12...15

When the module detects any of the conditions described for bits 12...15, it:

- sets the corresponding bit.
- blinks the status LED on the front panel for the channel having the fault.

The module is designed to detect the following fault conditions.

Open-circuit Detection (Bit 12)

The module tests all enabled channels for an open-circuit condition each time it scans its inputs. Possible causes of an open circuit include:

- broken thermocouple or CJC thermistor.
- thermocouple or CJC thermistor wire cut or disconnected.

Out-of-range Detection (Bit 13 for under-range, bit 14 for over-range)

The module tests all enabled channels for an out-of-range condition each time it scans its inputs. Possible causes of an out-of-range condition include:

- the temperature is too hot or too cold for the thermocouple being used.
- a type B, C, or D thermocouple may be registering a °F value in EU x1 beyond the range allowed by the SLC processor (beyond 32,767) for the data word.
- a CJC thermistor may be damaged or the temperature within the cabinet containing the module may be outside the CJC thermistor range limits.

Invalid Channel Configuration (Bit 15)

The module sets this fault bit when it detects the following invalid configurations:

- Configuration bits 0...3: invalid input type = 1 1 0 0 , or 1 1 0 1, or 1 1 1 0
- Configuration bits 6...7: invalid code for open circuit mode = 1 1
- Configuration bits 9...10, and 12...15: invalid non-zero bit setting

Ladder Programming Examples

Earlier chapters explained how configuration words define channel operation. This chapter shows examples of ladder logic that you write to:

- load configurations into the output image file to be scanned to the module.
- change the configuration of a channel.
- verify that the change in configuration occurred.
- process a channel input value with a PID instruction.
- monitor channel status.

We start with some basic concepts of the SLC processor.

Processor Basics

For the examples in this chapter, we have assigned the module to slot 3 and have addressed ladder logic files in the SLC processor as follows:

- Configurations are stored in words 0...3 of integer file #N10
- Configurations are scanned to the module from output image words O:3.0 through O:3.3
- Channel data words and channel status words are scanned from the module into input image words I:3.0 through I:3.3 and I:3.4 through I:3.7, respectively

During the program scan, the SLC processor follows the ladder logic instructions that you create to perform such functions as:

- copy or move configurations from integer file #N10 to the output image file to be scanned to the module during the next I/O scan.
- verify a change in configuration by comparing the channel status word with the channel configuration word for equality.
- examine channel status bits to see if the module flagged a fault condition.
- autocalibrate a channel by cycling the channel enable bit on and off.

During the I/O scan, the SLC processor scans configuration words from its output image file to the module, and scans data and status words from the module to its input image file. The SLC processor scans its I/O following each program scan.

We repeat the configuration word because it is used often in the examples.

Configuration Word

15 14 13 12

11

10 9

8

7 6

5 4

3 2 1 0

Not Used

Channel Enable

Not Used

Temp Units

Response to Open-circuit

Data Format

Type of Input

0 = Disable

0 = °C

0 0 = zero

0 0 = EU x1

0 0 0 = Type J

0 1 1 0 = Type B

1 = Enable

1 = °F

0 1 = FS

0 1 = EU x10

0 0 0 1 = Type K

0 1 1 1 = Type N

1 0 = LS

1 0 = Scaled PID

0 0 1 0 = Type T

1 0 0 0 = ±50 mV

1 1 = Prop Counts

0 0 1 1 = Type E

1 0 0 1 = ±100 mV

0 1 0 0 = Type R

1 0 1 0 = Type C

0 1 0 1 = Type S

1 0 1 1 = Type D

Example Configuration Word with These Parameters:

channel enabled, °C, zero for open-circuit, EU x10, Type K thermocouple

0 0 0 0

1

0 0

1

0 0

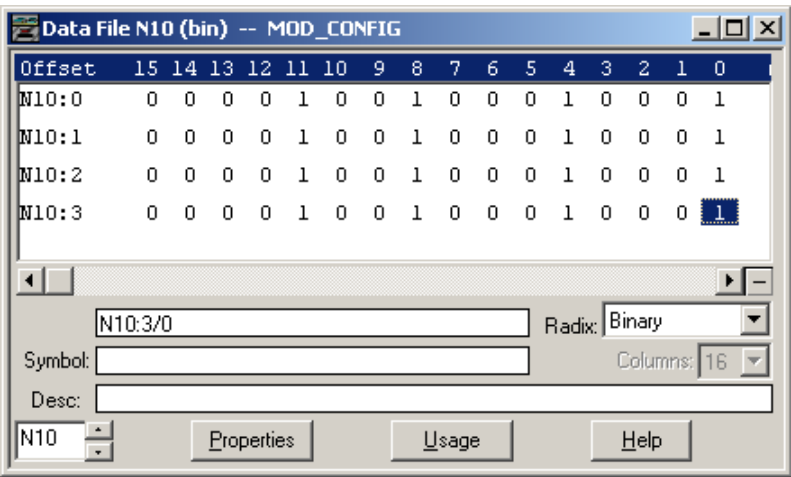
0 1

0 0 0 1

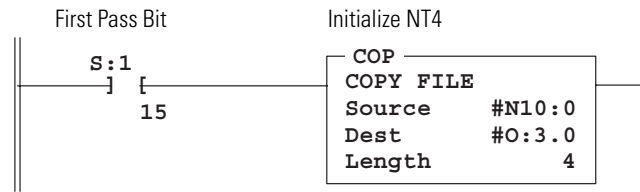
Load Channel Configurations for Transfer to the Module

This example shows you how to set configuration bits and transfer configuration data of all four channels to the module with a single File Copy instruction.

- 1. In RSLogix 500 software, open the data file N10 to configure the module parameters.



2. Program a rung of ladder logic to copy the integer file #N10 into output image file O:3.0 through O:3.3.



When cycling power, bit S:1/15 is set for the first program scan. It enables the Copy instruction to load configurations into the output image file for transfer to the module in the

Change a Channel Configuration

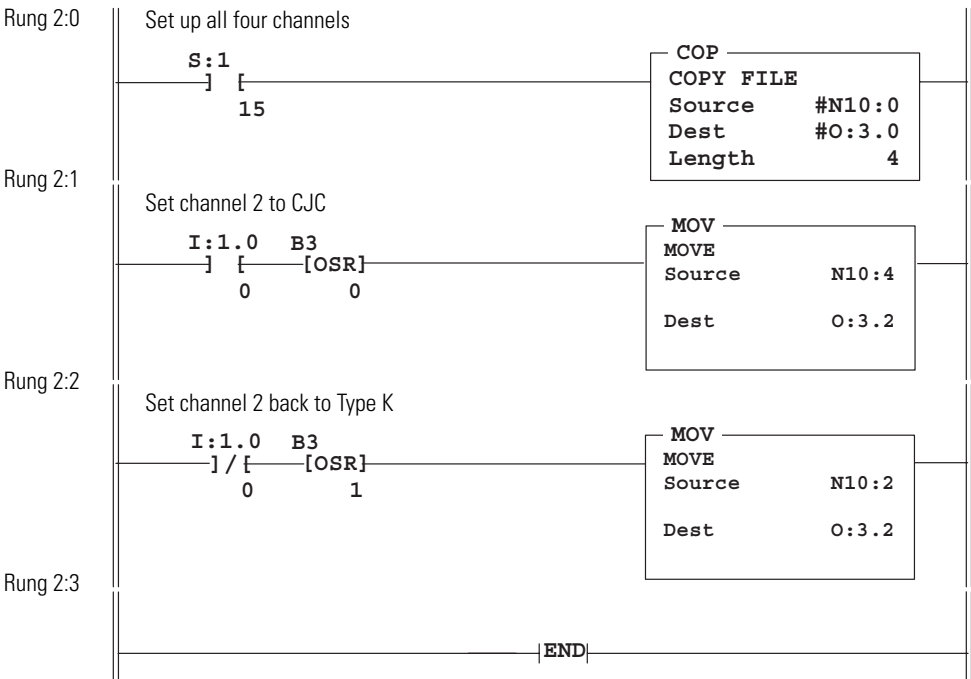
The following example explains how to change the channel configuration word when the channel is currently enabled.

EXAMPLE

Change the channel configuration word to read the temperature inside the control cabinet as read by the CJC thermistor. Then restore the original channel configuration.

We use #N10:4 to store the new configuration word. Consider input I:1.0/0 as a push button switch for changing configurations. The one-shot instruction OSR enables the Copy instruction once no matter how long the operator presses the push button switch.

Program



Data File N10 (bin) -- MOD_CONFIG

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

N10:0/0 Radix: Binary
Symbol: Columns: 16
Desc:
N10 Properties Usage Help

IMPORTANT

While the module changes the channel configuration, it does not monitor inputs to any channel.

For the delay in reading inputs, refer to Channel Cut-off Frequency, Update Time, and Step Response in Chapter 4.

Verify Changes to a Channel Configuration

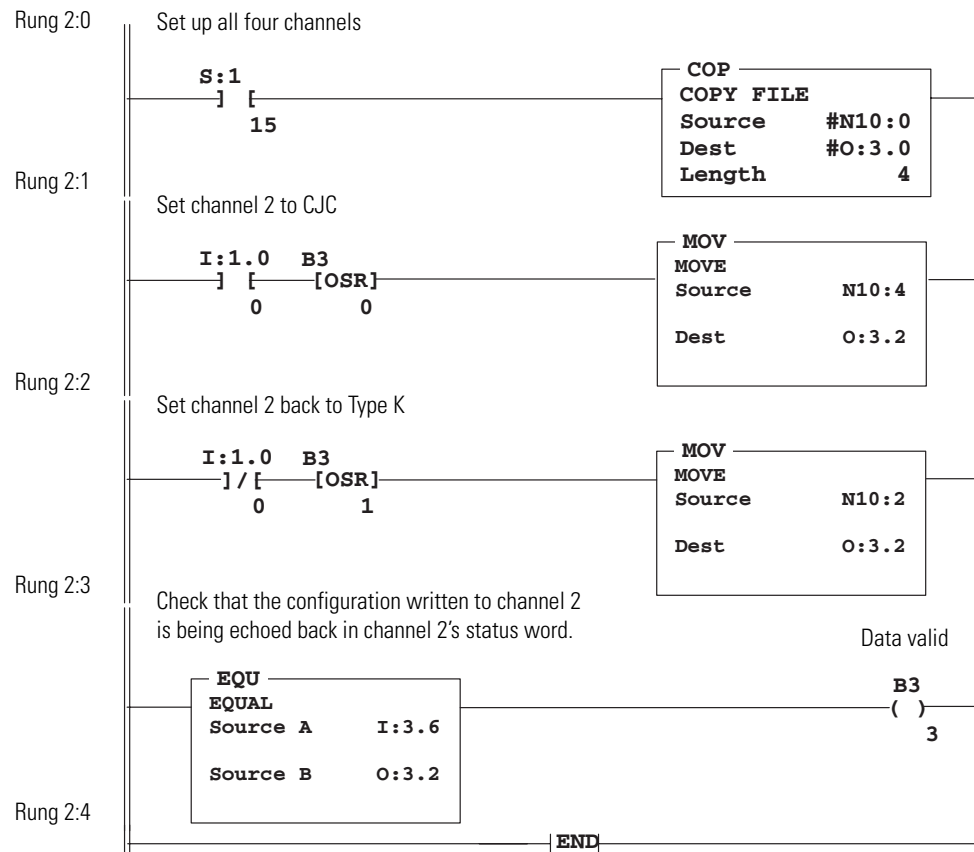
When changing a channel configuration, there is always a delay until the ladder logic reads the new data word based on the new configuration. Therefore, it is important to verify that the module successfully stored the new channel configuration word. The following example explains how to verify a change to a channel configuration.

EXAMPLE

Change the channel configuration word and verify the change by comparing the resulting status word with the configuration word for equality.

We do this by adding rung 2:3 to the rungs in the previous example.

Program



Data File N10 (bin) -- MOD_CONFIG

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

Symbol: N10:0/0 Radix: Binary Columns: 16

Desc: N10

Properties Usage Help

Process a Channel Input with the PID Instruction

The module was designed to input a channel directly to a PID instruction of an SLC 5/02 processor or later without the need of an intermediate scale operation.

EXAMPLE

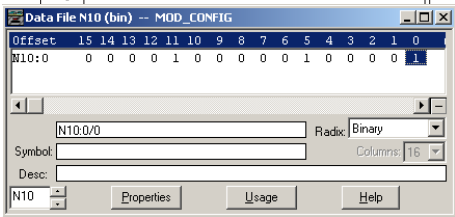
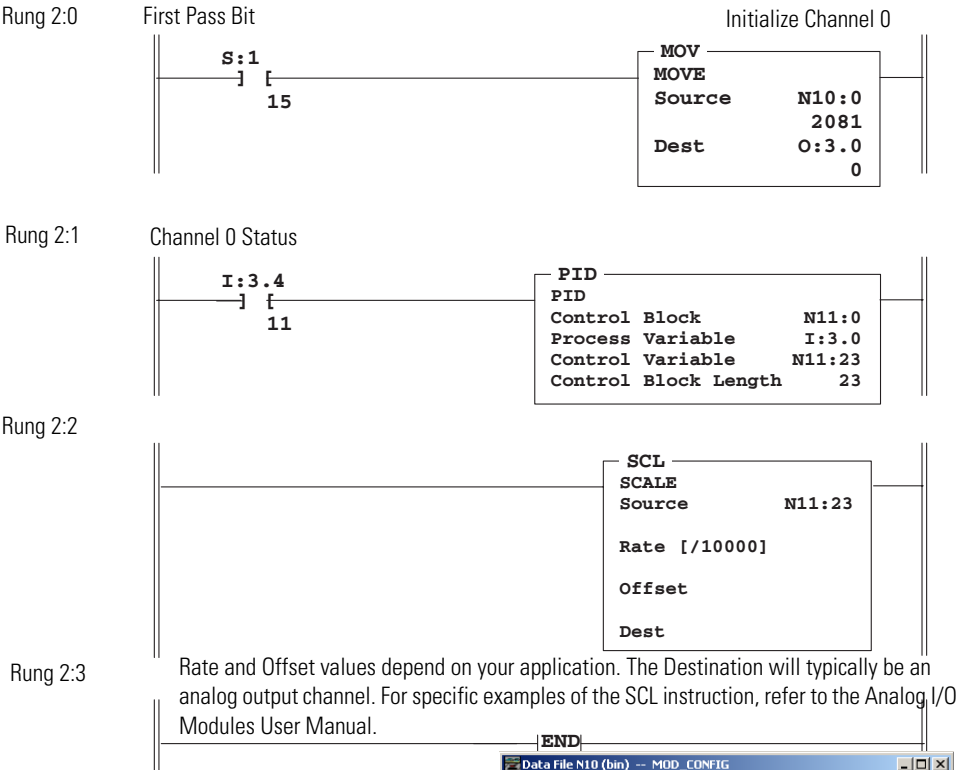
Use channel data as the process variable for the PID instruction.

Use channel data as the process variable for the PID instruction.

1. Select scaled-for-PID as the data type in the channel configuration word.
2. Specify channel data word as the process variable for the PID instruction.

In this example, the value 2081 is the numeric equivalent of configuration word N10:0 for channel 0. It is configured for a type K thermocouple, scaled-for-PID, zero the signal for an open input, °C, and channel enabled.

Program



Monitor Channel Status Bits

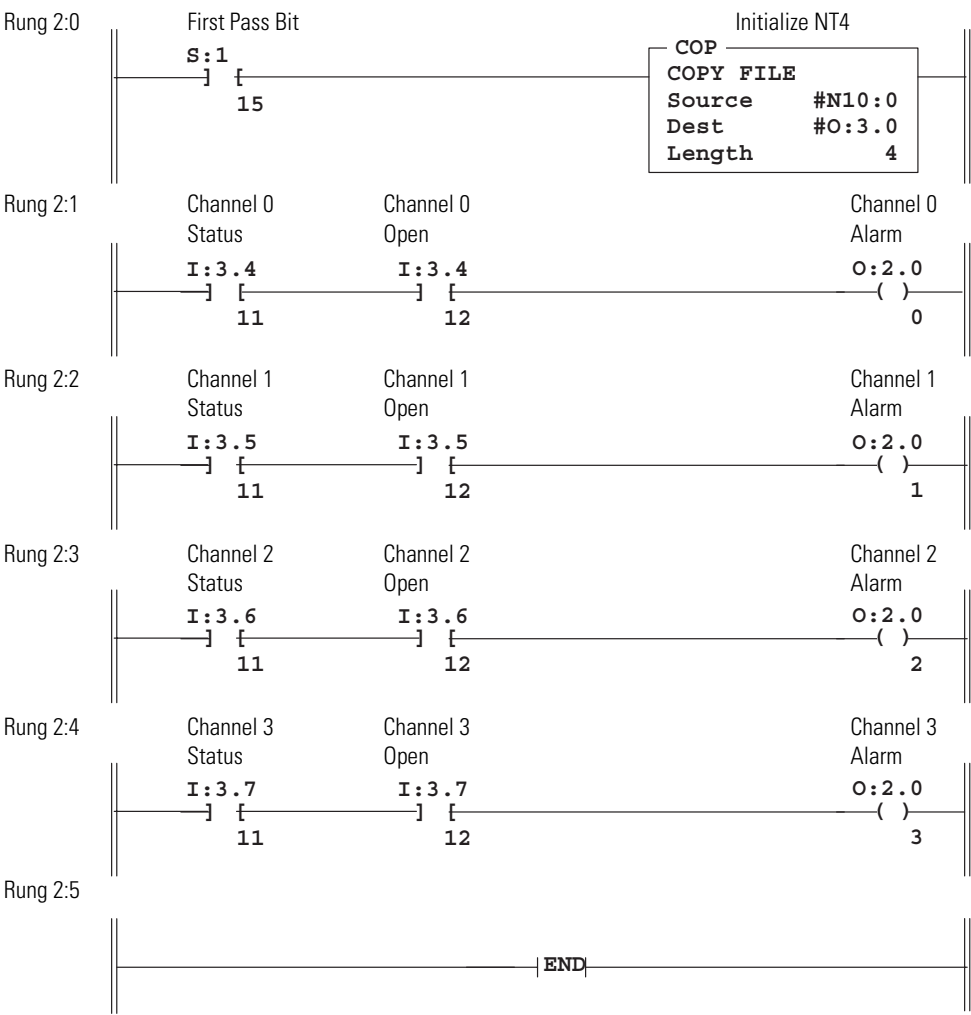
This example shows how you could monitor the open-circuit error bit of each channel and set an alarm bit if the module detects an open input. An open-circuit error can occur if a thermocouple or CJC thermistor wire breaks or becomes disconnected from the terminal block.

In this example, we monitor the channel enable bit (bit 11) and the open-input bit (bit 12) in channel status words I:3.4 through I:3.7, and use output image bits O:2.0/0...3 as alarm bits.

IMPORTANT

If a CJC thermistor is not installed or is damaged, all four alarms are set, and all four channel LEDs blink.

Program



Data File N10 (bin) -- MOD_CONFIG

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

N10:3/0 Radix: Binary Columns: 16

Symbol: Desc: N10 Properties Usage Help

Module Diagnostics and Troubleshooting

This chapter describes troubleshooting with channel-status and module-status LED indicators. It explains the types of conditions that might cause the module to flag an error, and suggests what corrective action you could take. Topics include:

- module and channel diagnostics.
- status indicators.
- troubleshooting flowchart.
- replacement parts.
- contacting Rockwell Automation.

Module and Channel Diagnostics

The module operates at two levels.

- Module level
- Channel level

Module level operation includes functions such as cycling power, configuration, and communication with the SLC processor. ON indicates the module is OK. OFF indicates a fault.

Channel level operation includes functions such as data conversion and open-circuit detection. ON indicates the channel is OK. Blinking indicates a fault.

The module performs internal diagnostics at both levels, and immediately indicates detected error conditions with either of its status LED indicators. When a status LED indicator is continuously ON, the status is OK.

Module Diagnostics When Cycling Power

When you cycle the module's power, the module performs a series of internal diagnostic tests. If the module detects a failure, its module status LED indicator remains off.

Channel Diagnostics

When a channel is enabled, the module checks for a valid configuration. Then on each scan of its inputs, the module checks for out-of-range and open-circuit fault conditions of its inputs including the CJC thermistor.

When the module detects a failure of any channel diagnostic test, it causes the channel status LED indicator to blink and sets the corresponding channel fault bit (bits 12...15 of the channel status word). Channel fault bits and LED indicators are self-clearing when fault conditions are corrected.

IMPORTANT

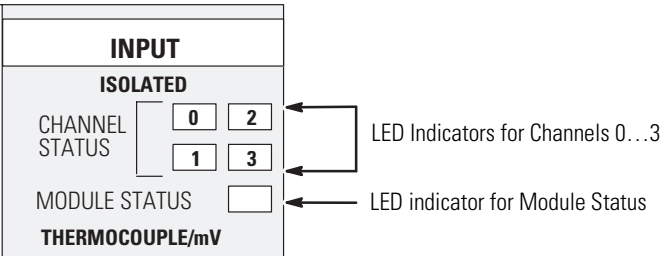
If you clear the channel enable bit, channel status bits are reset.

LED Indicators

The module has five status LED indicators.

- Four channel-status LED indicators, numbered to correspond with each channel
- One module-status LED indicator

LED Indicators



LED Indicator Troubleshooting Tables

Module-status LED Indicator

If module status LED indicator is	Then	Take this corrective action
On	The module is OK.	No action required.
Off	The module is turned off, or it detected a module fault.	Cycle power. If the condition persists, call your local distributor or Allen-Bradley customer service for assistance.

Module-status and Channel-status LED Indicators

If Module Status LED Indicator is	And Channel Status LED Indicator is	Then	Take This Corrective Action
On	On	The channel is enabled.	No action required.
	Blinking	The module detected: open-circuit condition under-range condition over-range condition channel configuration error.	Examine error bits in the status word: if bit 12 = 1, the input has an open-circuit; if bit 13 = 1, the input value is under-range; if bit 14 = 1, the input value is over-range; if bit 15 = 1, the configuration is invalid.
	Off	The module is cycling power, or the channel is disabled.	No action required.

Channel-status LED Indicators (green)

The channel-status LED indicator operates with status bits in the channel status word to indicate the following faults detected by the module:

- Invalid channel configuration
- An open-circuit input
- Out-of-range errors

When the module detects any of the following fault conditions, it causes the channel-status LED indicator to blink and sets the corresponding fault bit in the channel status word. Channel fault bits (bits 12...15) and channel-status LED indicators are self-clearing when fault conditions are corrected.

Open-circuit Detection (Bit 12)

The module tests all enabled channels for an open-circuit condition each time it scans its inputs. Possible causes of an open-circuit include:

- broken thermocouple or CJC thermistor.
- thermocouple or CJC thermistor wire cut or disconnected.

Out-of-range Detection (Bit 13 for under-range, bit 14 for over-range)

The module tests all enabled channels for an out-of-range condition each time it scans its inputs. Possible causes of an out-of-range condition include the following:

- The temperature is too hot or too cold for the thermocouple being used.
- A type B thermocouple may be registering a °F value in EU x1 beyond the range allowed by the SLC processor (beyond 32,767) for the data word.
- A CJC thermistor may be damaged or the temperature within the cabinet containing the module may be outside the CJC thermistor range limits.

Invalid Channel Configuration (Bit 15)

The module sets this fault bit when it detects any of the following invalid configurations:

- Configuration bits 0...3: invalid input type = 1 1 0 0 , or 1 1 0 1, or 1 1 1 0
- Configuration bits 6...7: invalid code for open circuit mode = 1 1
- Configuration bits 9...10, and 12...15: invalid non-zero bit setting

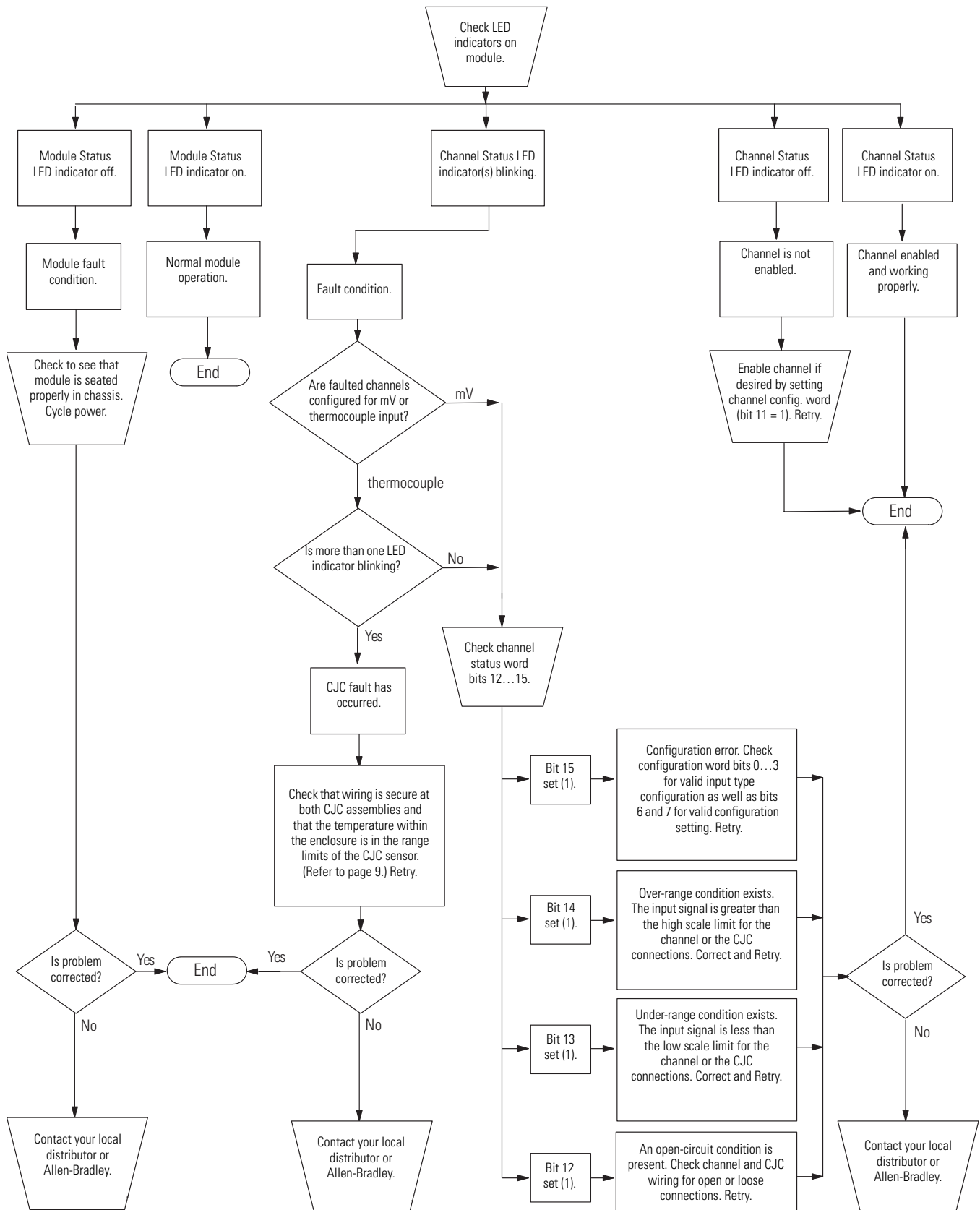
Module-status LED (green) Indicator

The module-status LED indicator shows when the module detects a non-recoverable fault when power is cycled or during operation. For this type of fault, the module:

- no longer communicates with the SLC processor.
- disables all channels.
- clears all data and status words.

A module failure is non-recoverable and requires the assistance of your local distributor or Allen-Bradley Support Services (see Preface).

Troubleshooting Flowchart



Replacement Parts

The module has the following replaceable parts.

Part	Part Number
Replacement Terminal Block	1746-RT32
Replacement Terminal Cover	1746-R13 Series B
1746-INT4 User Manual	1746-UM614

Contacting Rockwell Automation

If you need to contact Rockwell Automation 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 doing, LED indicator status, and bit status of I/O image words (channel configuration and status) for the module
- Fault code if the SLC processor is faulted
- Processor type and firmware (FRN) number from label on processor
- A list of things you have already tried to remedy the problem
- Hardware types in the system including I/O modules and chassis

Application Programming Examples

This chapter provides two application examples to help you use the module.

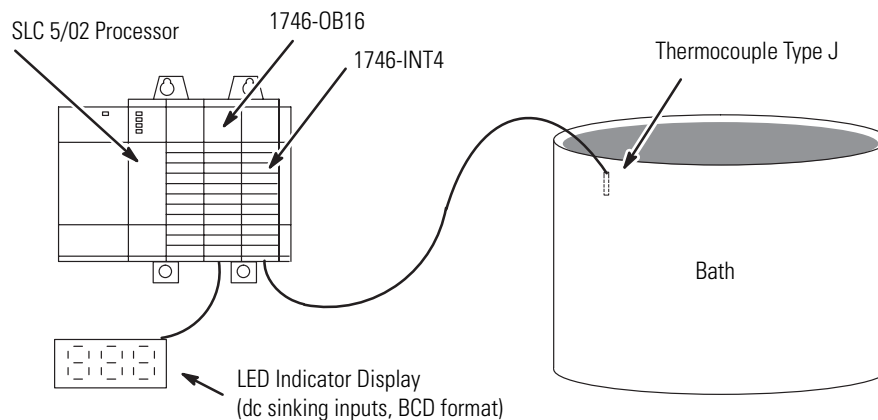
- Basic example
- Supplementary example

The basic example lets you display a temperature.

The supplementary example lets you manually select the display of temperature in °C or °F.

Basic Example (to display a temperature)

This example lets you display the temperature of a bath °F on an LED indicator display device. The display device requires BCD data, so the program must convert the temperature reading to BCD.



Channel Configuration

Configure the thermocouple channel with the following setup:

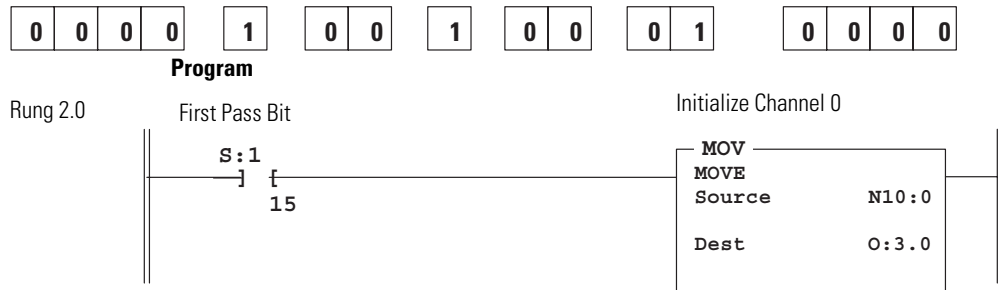
- Type J thermocouple (bits 3...0)
- °F displayed in whole degrees with EU = x10 (bits 8, 5, 4)
- Set the data word to zero in the event of an open-circuit (bits 7, 6)

Configuration Word

15 14 13 12	11	10 9	8	7 6	5 4	3 2 1 0	
Not Used	Channel Enable	Not Used	Temp Units	Response to Open-circuit	Data Format	Type of Input	
	0 = Disable		0 = °C	0 0 = zero	0 0 = EU x1	0 0 0 = Type J	0 1 1 0 = Type B
	1 = Enable		1 = °F	0 1 = FS	0 1 = EU x10	0 0 0 1 = Type K	0 1 1 1 = Type N
				1 0 = LS	1 0 = Scaled PID	0 0 1 0 = Type T	1 0 0 0 = 0...100 mV
					1 1 = Prop Counts	0 0 1 1 = Type E	1 0 0 1 = ±100
						0 1 0 0 = Type R	1 0 1 0 = Type C
						0 1 0 1 = Type S	1 0 1 1 = Type D

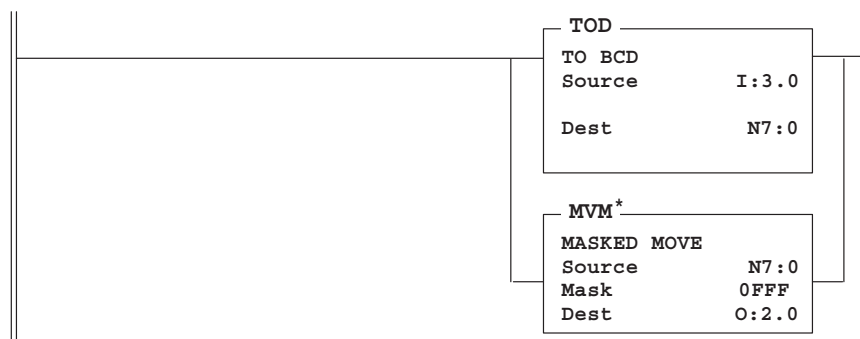
Example Configuration Word with These Parameters:
channel enabled, °F, zero for open-circuit, EU x10, Type J thermocouple

Example Configuration Word with These Parameters:
channel enabled, °F, zero for open-circuit, EU x10, Type J thermocouple



Rung 2.1

Convert the channel 0 data word ($^{\circ}\text{F}$) to BCD and write this to the LED indicator display.



The use of the masked move instruction with the OFF mask lets you use outputs 12, 13, 14 and 15 for other output devices in your system. The seven segment display uses outputs 0 ...11.

Rung 2.2

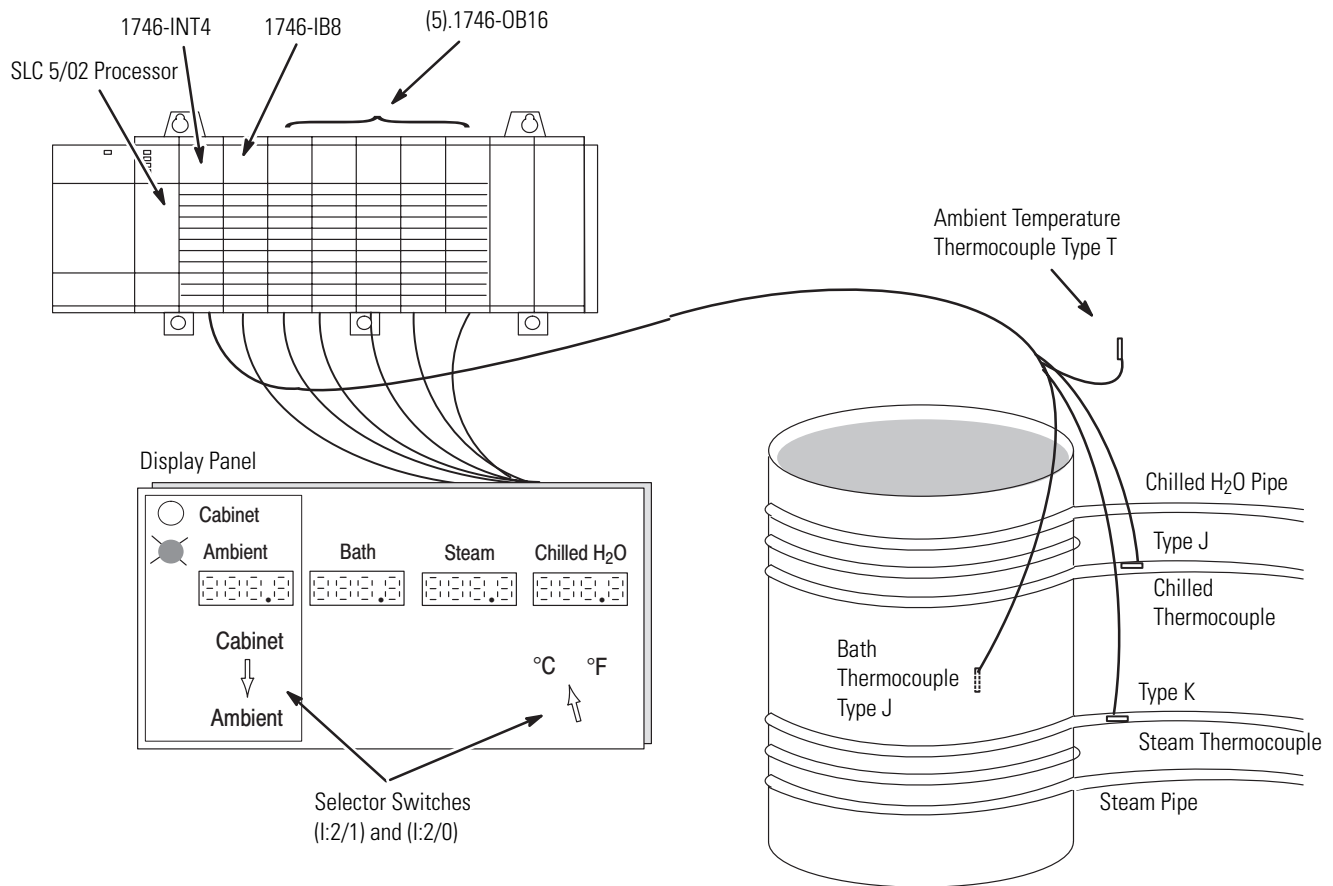


Data Table

address	15	data	0	address	15	data	0
N10:0	0000	1001 0001 0000	0000				

Supplementary Example (select display in °C or °F)

This example shows how to display the temperature of several thermocouples at display panel. A selector switch (I:2/0) lets the operator choose between displaying temperatures in °C or °F. A second selector switch (I:2/1) lets the operator switch a display between the ambient temperature near the bath and the temperature inside the control cabinet containing the SLC controller. Each display is a four digit, seven segment LED indicator display with the last digit representing tenths of a degree. The displays have dc-sinking inputs and use a BCD data format.



Channel Configuration

All channels are configured for:

- display temperature to tenths of a degree.
- zero data word in the event of an open-circuit.

Configuration setup for ambient thermocouple:

- channel 0.
- type T thermocouple.

Configuration setup for bath thermocouple:

- channel 1.
- type J thermocouple.

Configuration setup for steam thermocouple:

- channel 2.
- type K thermocouple.

Configuration setup for chilled H₂O thermocouple:

- channel 3.
- type J thermocouple.

Configuration setup for cabinet temperature:

- channel 0.
- CJC temperature.

Configuration Word

15 14 13 12	11	10 9	8	7 6	5 4	3 2 1 0	
Not Used	Channel Enable	Not Used	Temp Units	Response to Open-circuit	Data Format	Type of Input	
	0 = Disable 1 = Enable		0 = °C 1 = °F	0 0 = zero 0 1 = FS 1 0 = LS	0 0 = EU x1 0 1 = EU x10 1 0 = Scaled PID 1 1 = Prop Counts	0 0 0 0 = Type J 0 0 0 1 = Type K 0 0 1 0 = Type T 0 0 1 1 = Type E 0 1 0 0 = Type R 0 1 0 1 = Type S	0 1 1 0 = Type B 0 1 1 1 = Type N 1 0 0 0 = 0...100 mV 1 0 0 1 = ±100 1 0 1 0 = Type C 1 0 1 1 = Type D 1 1 1 1 = CJC Temp
0 0 0 0	1	0 0	x	0 0	0 0	0 0 1 0	Channel 0 (Ambient)
0 0 0 0	1	0 0	x	0 0	0 0	0 0 0 0	Channel 1 (Bath)
0 0 0 0	1	0 0	x	0 0	0 0	0 0 0 1	Channel 2 (Steam)
0 0 0 0	1	0 0	x	0 0	0 0	0 0 0 0	Channel 3 (Chilled H ₂ O)
0 0 0 0	1	0 0	x	0 0	0 0	1 1 1 1	Channel 3 (Cabinet)

Program Setup

Follow these steps to set up the program.

1. Set up two configuration words for each channel in file N10, one for °C and the other for °F.

Include two configuration words for the CJC temperature in the cabinet containing the SLC controller.

N10 Channels/Configuration Words

Channel	Configuration Word Addresses	
	°F	°C
0	N10:0	N10:4
1	N10:1	N10:5
2	N10:2	N10:6
3	N10:3	N10:7
CJC	N10:8	N10:9

2. Write ladder logic to send channel configurations to the module when the operator changes the °C/°F or the ambient/cabinet selector switch.

The OSR instruction (one-shot rising) makes these configuration changes edge-triggered. That means the module is reconfigured once each time the operator changes a switch position.

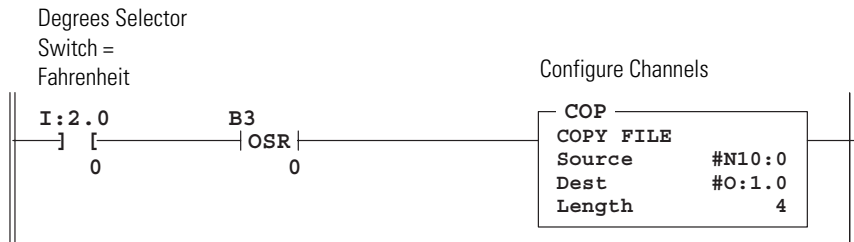
3. Write ladder logic to monitor the channel 0 status word to determine whether ambient or cabinet temperature is being displayed, and energize the appropriate pilot light.
4. Write ladder logic to convert thermocouple data words to BCD and send them to the LED indicator displays.

Program

The first six rungs change channel configurations based on the position of the two selector switches.

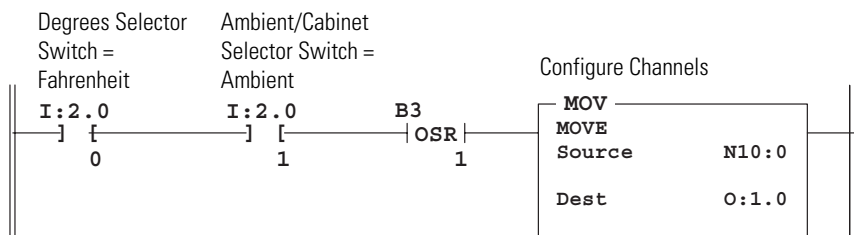
Rung 2.0

If the degrees selector switch is switched to Fahrenheit, configure all four channels to read in degrees Fahrenheit. The default for channel 0 is to read the ambient temperature thermocouple.



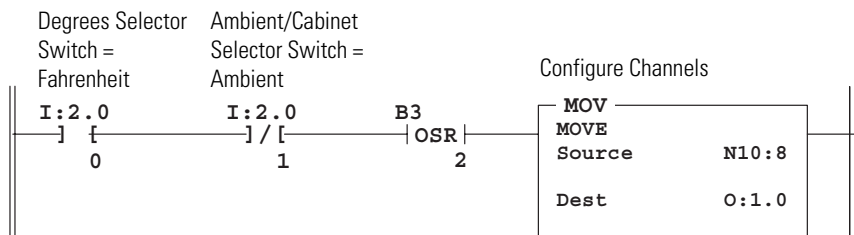
Rung 2.1

If the ambient/cabinet selector switch is switched to ambient, and the degrees selector switch is switched to Fahrenheit, configure channel 0 to read the ambient temperature thermocouple in degrees Fahrenheit.



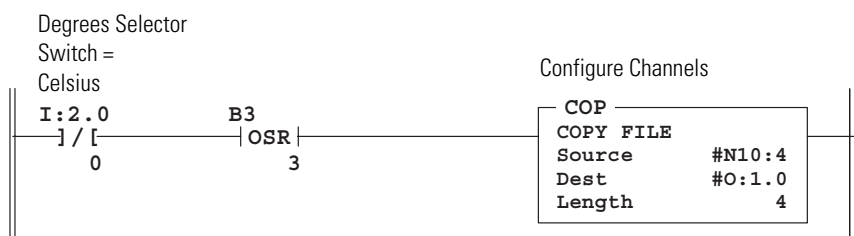
Rung 2.2

If the ambient/cabinet selector switch is switched to cabinet, and the degrees selector switch is switched to Fahrenheit, configure channel 0 to read the CJC sensor in degrees Fahrenheit.



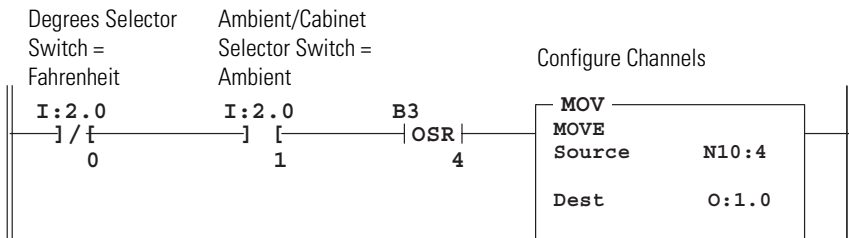
Rung 2.3

If the degrees selector switch is switched to Celsius, configure all four channels to read in degrees Celsius. The default for channel 0 is to read the ambient temperature thermocouple.



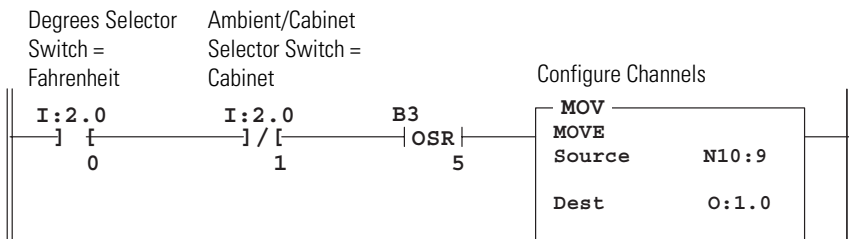
Rung 2.4

If the ambient/cabinet selector switch is switched to ambient, and the degrees selector switch is switched to Celsius, configure channel 0 to read the ambient temperature thermocouple in degrees Celsius.



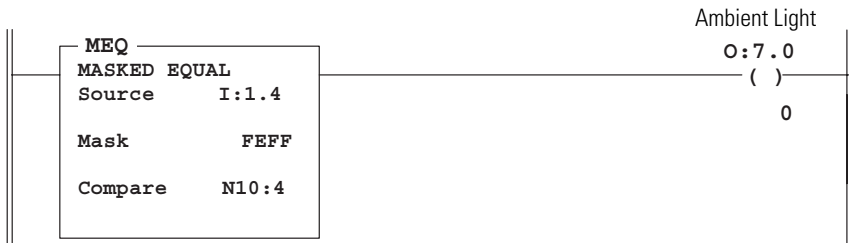
Rung 2.5

If the ambient/cabinet selector switch is switched to cabinet, and the degrees selector switch is switched to Celsius, configure channel 0 to read the CJC sensor in degrees Celsius.



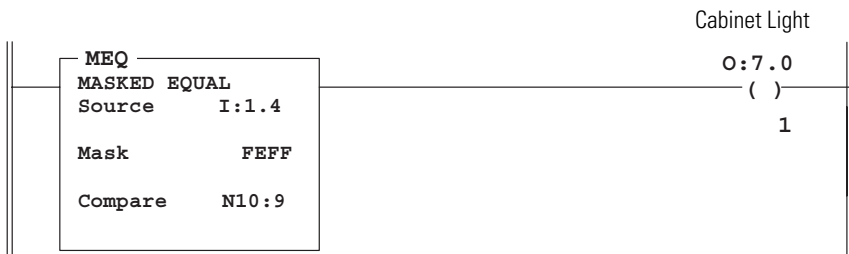
Rung 2.6

If channel 0 is configured to read the ambient thermocouple, energize the ambient pilot light on the panel.



Rung 2.7

If channel 0 is configured to read the CJC sensor, energize the cabinet pilot light on the panel.



Rung 2.8

Convert data words to BCD format and send them to the LED indicator displays.

Write Ambient or Cabinet
Temperature to the Display



Rung 2.9

Write Bath Temperature
to the Display



Rung 2.10

Write Steam Temperature
to the Display

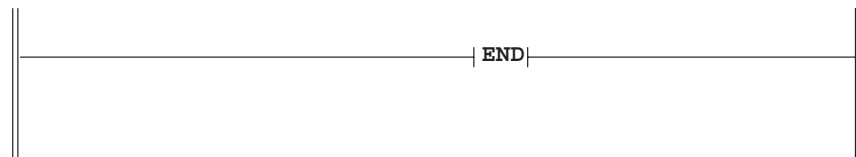


Rung 2.11

Write Chilled Temperature
to the Display



Rung 2.12



Data Table

address	15	data				0	address	15	data				0
N10:0	0000	1101	0000	0010			N10:5	0000	1100	0000	0000		
N10:1	0000	1101	0000	0000			N10:6	0000	1100	0000	0001		
N10:2	0000	1101	0000	0001			N10:7	0000	1100	0000	0000		
N10:3	0000	1101	0000	0000			N10:8	0000	1101	0000	1111		
N10:4	0000	1100	0000	0010			N10:9	0000	1100	0000	1111		

Module Specifications

This appendix lists the specifications for the 1746-INT4 Thermocouple/mV Isolated Input Module.

Electrical Specifications

Attribute	Value
Backplane current consumption	110 mA @ 5V dc 85 mA @ 24V dc
Backplane power consumption	0.6 W max (0.55 W @ 5V dc, 2 W @ 24V dc)
Number of channels	4 (backplane and channel-to-channel isolated)
I/O chassis location	Any I/O module slot except slot 0
A/D conversion method	Sigma-delta modulation
Input filtering	Analog filter with low pass digital filter
Normal mode rejection (between [+] input and [-] input)	Greater than 50 dB @ 50 Hz Greater than 60 dB @ 60 Hz
Common mode rejection (between inputs and chassis ground)	Greater than 120 dB at 50/60 Hz (with 1 k Ω imbalance)
Channel bandwidth (-3 dB)	8 Hz
Calibration	Once yearly, if required
Isolation	1000V transient or 150V ac continuous channel-to-channel or channel-to-backplane

Physical Specifications

Attribute	Value
LED indicators	5, green status indicators, one for each of 4 channels and one for module status
Module ID code	3515
Recommended cable: for thermocouple inputs ... for mV inputs ...	Shielded twisted pair thermocouple extension wire ⁽¹⁾ Alpha 5121 or equivalent

Attribute	Value
Max wire size	Two 1.6 mm (14 AWG) wires per terminal
Max cable impedance	150 Ω max loop impedance, for < 1LSB error
Terminal strip	Removable, catalog number 1746-RT32

(1) Refer to the thermocouple manufacturer for the correct extension wire.

Environmental Specifications

Attribute	Value
Temperature, operating	0... 60 °C (32...140 °F)
Temperature, storage	-40...85 °C (-40...185 °F)
Relative humidity	5...95% (without condensation)
Agency certification (when product is marked)	• CSA certified • CSA Class I, Division 2, Groups A, B, C, D certified Hazardous Locations • UL listed • CE marked for all applicable directives

Input Specifications

Attribute	Value
Type of input (selectable)	Thermocouple Type C 0...2317 °C (32...4201 °F) Thermocouple Type D 0...2317 °C (32...4201 °F) Thermocouple Type J -210...760 °C (-346...1400 °F) Thermocouple Type K -270...1370 °C (-454...2498 °F) Thermocouple Type T -270...400 °C (-454...752 °F) Thermocouple Type E -270...1000 °C (-454...1832 °F) Thermocouple Type R 0...1768 °C (32...3214 °F) Thermocouple Type S 0...1768 °C (32...3214 °F) Thermocouple Type B 300...1820 °C (572...3308 °F) Thermocouple Type N 0...1300 °C (32...2372 °F) 1.6 mm (14 AWG) Millivolt (-50...50 mV dc) Millivolt (-100...100 mV dc)
Thermocouple linearization	IPTS-68 standard, NBS MN-125, NBS MN-161
Cold junction compensation	Accuracy ± 1.5 °C (34.7 °F), 0... 70 °C (32...158 °F)
Input impedance	Greater than 10 M Ω

Attribute	Value
Temperature scale (selectable)	°C or °F and 0.1 °C or 0.1 °F
Millivolt scale, dc (selectable)	0.1 mV or 0.01 mV
Open-circuit detection leakage current	20 nA typical
Open-circuit detection (selectable)	Upscale, downscale, or zero
Time to detect open-circuit	5 s, typical
Input step response	0...99.9% in 600 ms (worst case)
Input resolution	See Input Resolution Graphs on following pages. They show the smallest measurable value based on combined hardware and software tolerances.
Display resolution	See Channel Data Word Resolution table on page 51.
Overall module accuracy @ 25 °C (77 °F)	See Module Accuracy Table below.
Overall module accuracy (0... 60 °C, 32... 140 °F)	See Module Accuracy Table below.
Overall module drift	See Module Accuracy Table below.
Module update time	Less than 500 ms
Channel turn-off time	Up to one module update time

Overall Accuracy

We define overall accuracy to include variances in cold-junction compensation, calibration, non-linearity, and resolution.

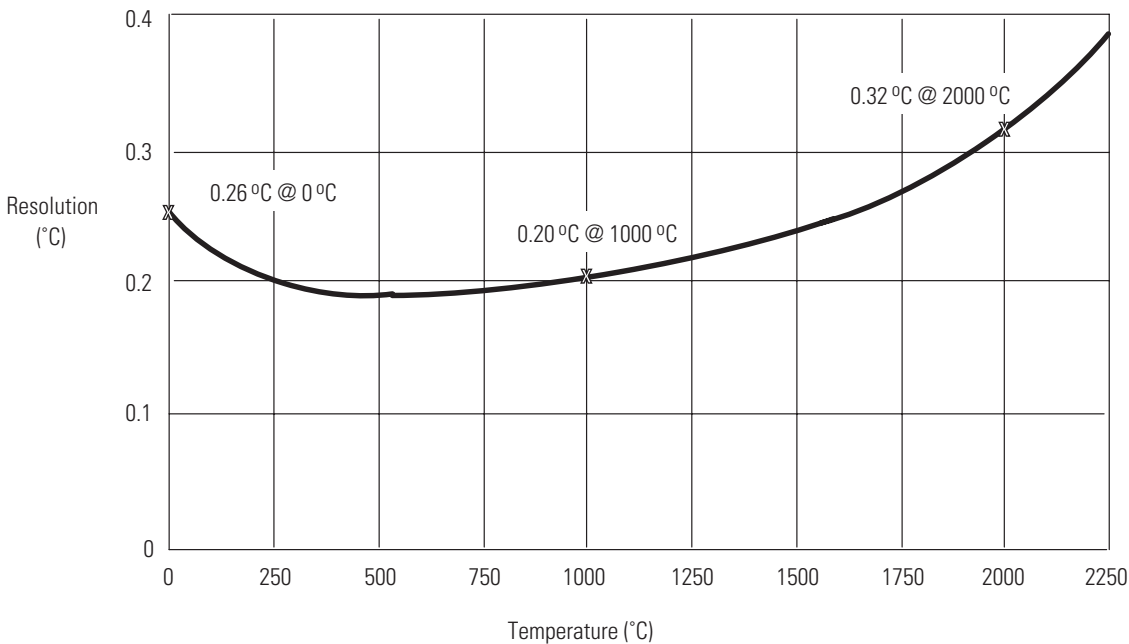
Input Type	Max Error ⁽¹⁾ @ 25 °C	Max Error ⁽¹⁾ @ 77 °F	Temperature Drift ⁽¹⁾ (0... 60 °C)
J	±1.60 °C	±2.88 °F	±0.042 °C/°C, °F/°F
K	±3.80 °C	±6.84 °F	±0.096 °C/°C, °F/°F
T	±2.05 °C	±3.69 °F	±0.025 °C/°C, °F/°F
E	±2.40 °C	±4.32 °F	±0.058 °C/°C, °F/°F
S	±2.38 °C	±4.29 °F	±0.131 °C/°C, °F/°F
R	±2.23 °C	±4.02 °F	±0.130 °C/°C, °F/°F
B	±3.83 °C	±6.90 °F	±0.109 °C/°C, °F/°F

Input Type	Max Error ⁽¹⁾ @ 25 °C	Max Error ⁽¹⁾ @ 77 °F	Temperature Drift ⁽¹⁾ (0... 60 °C)
N	±1.79 °C	±3.23 °F	±0.080 °C/°C, °F/°F
C	±2.28 °C	±4.11 °F	±0.270 °C/°C, °F/°F
D	±2.52 °C	±4.54 °F	±0.280 °C/°C, °F/°F
±50 mV	±50 µV	±50 µV	±0.5 µV/°C ±50 ppm/°C
±100 mV	±50 µV	±50 µV	±0.5 µV/°C ±50 ppm/°C

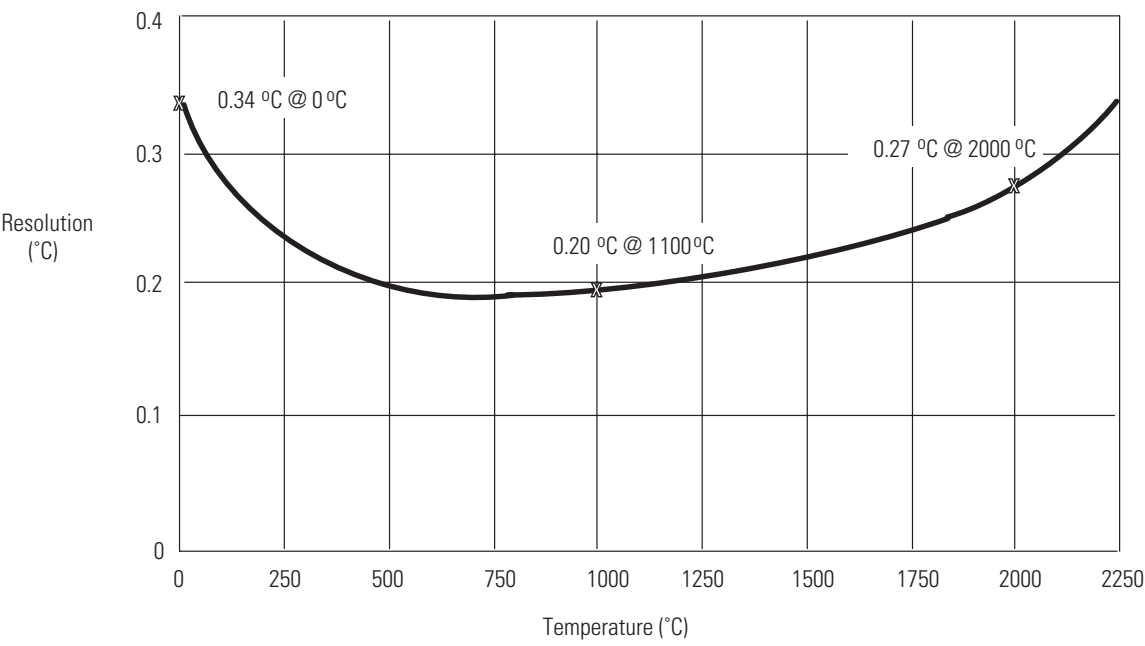
(1) Assumes the module terminal block temperature is stable.

Thermocouple Resolution

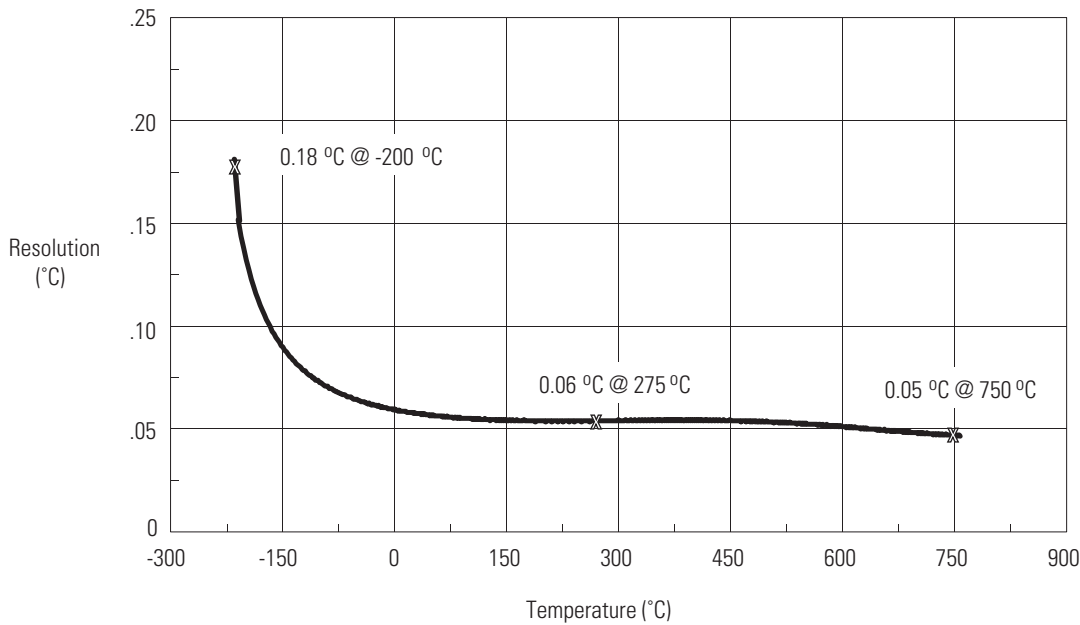
Type C Thermocouple



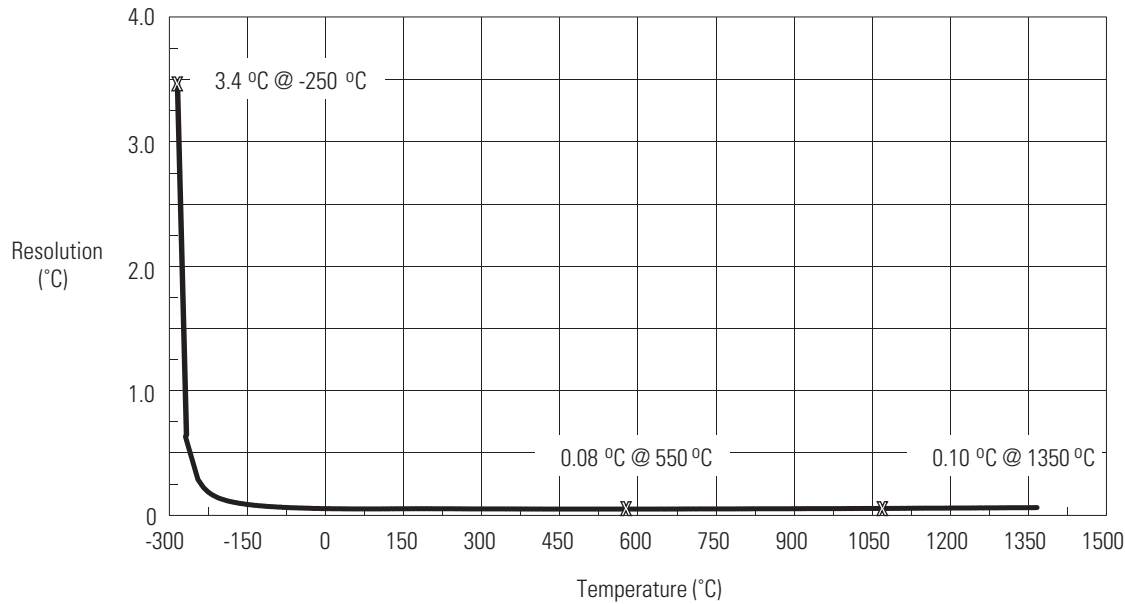
Type D Thermocouple

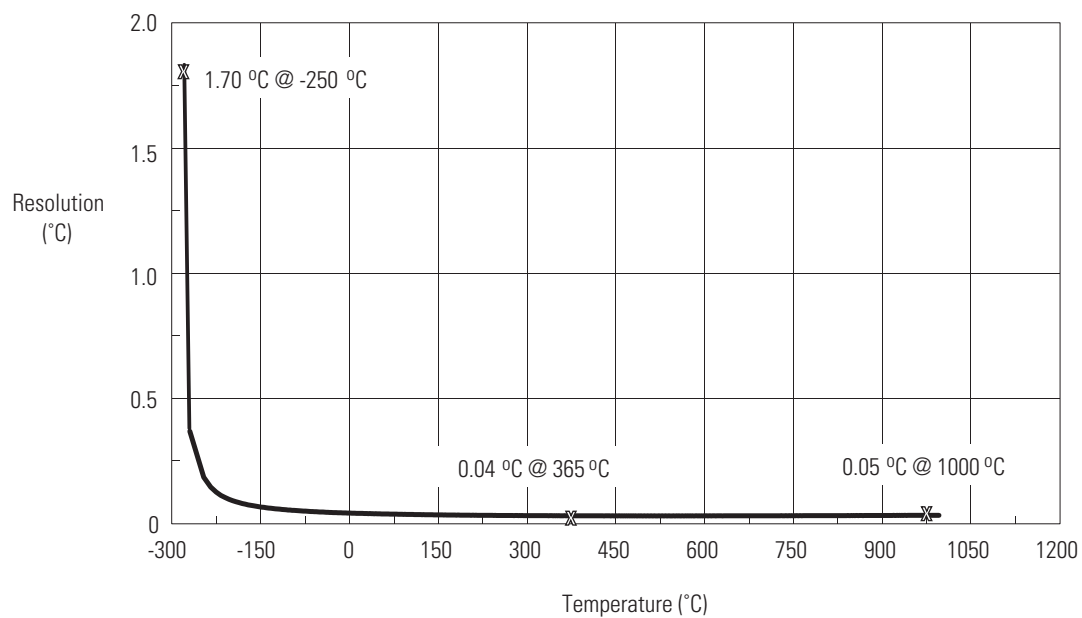
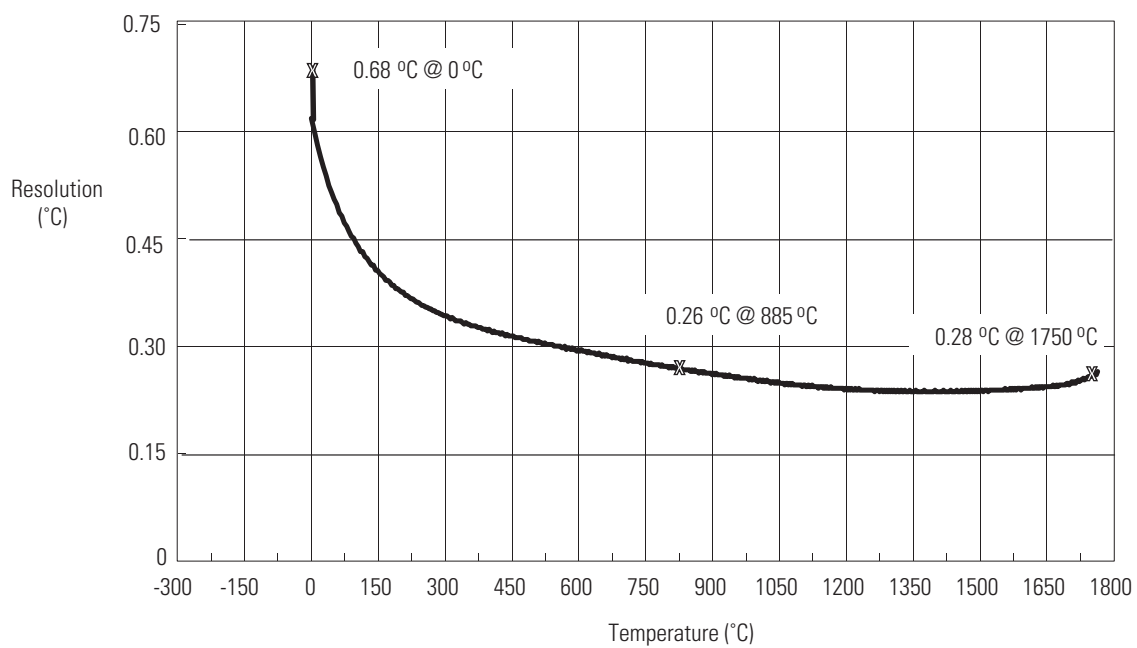


Type J Thermocouple

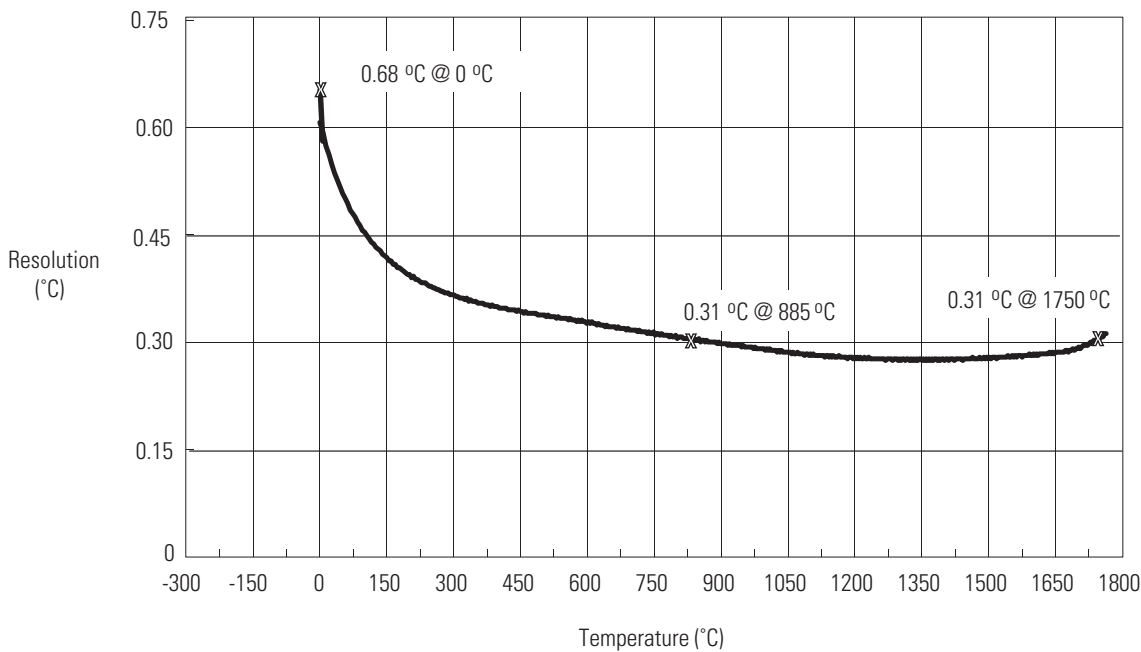


Type K Thermocouple

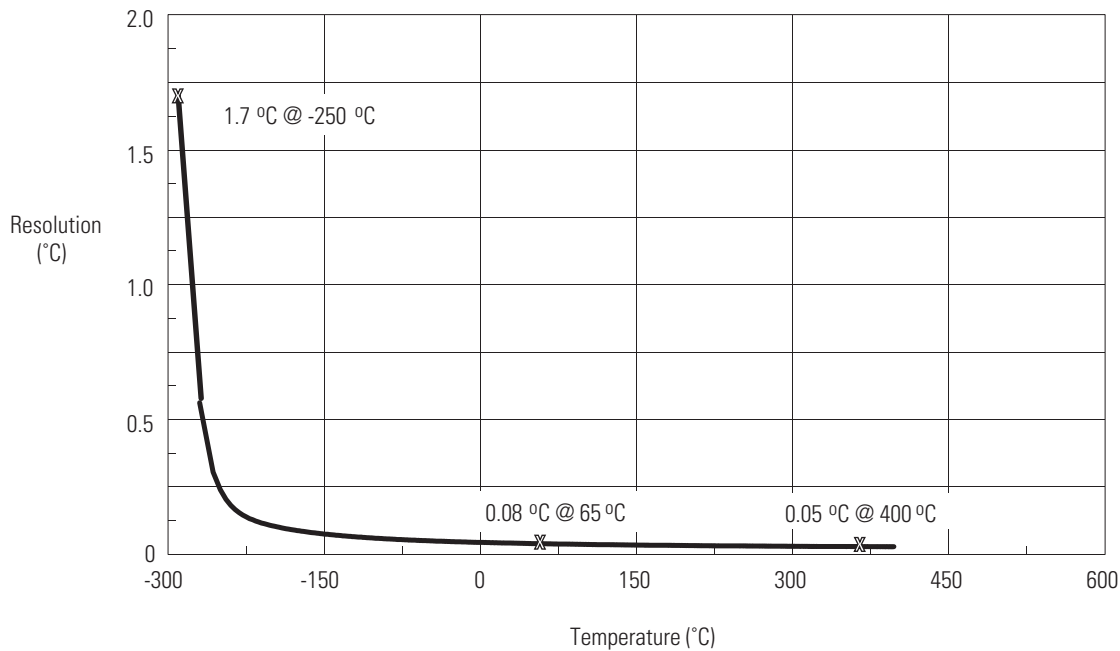


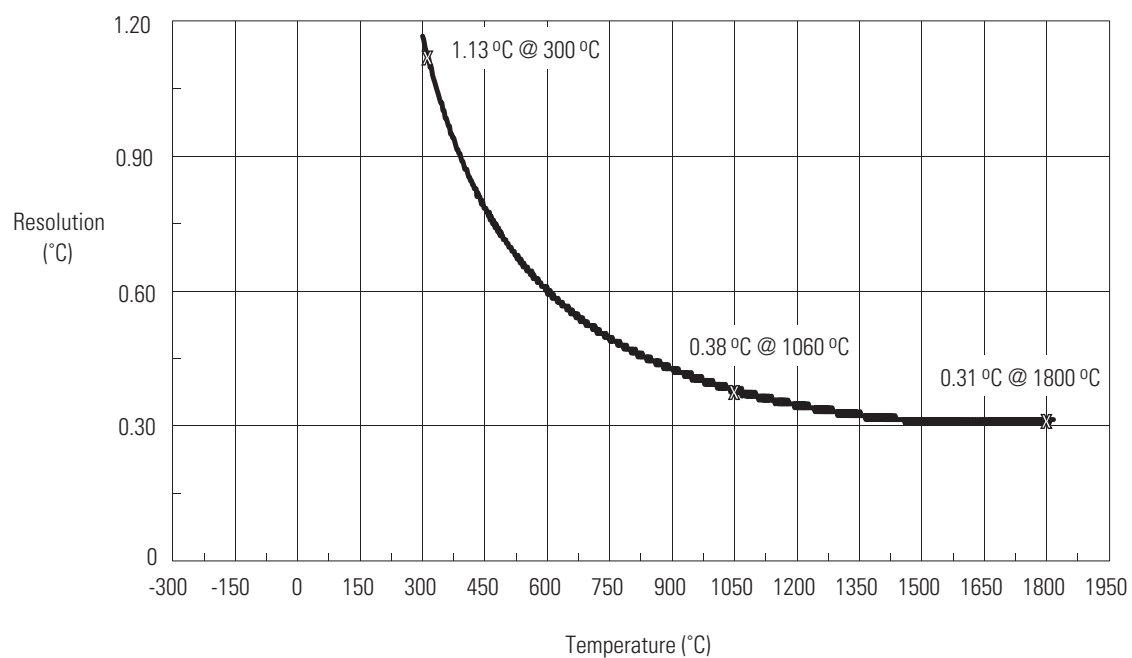
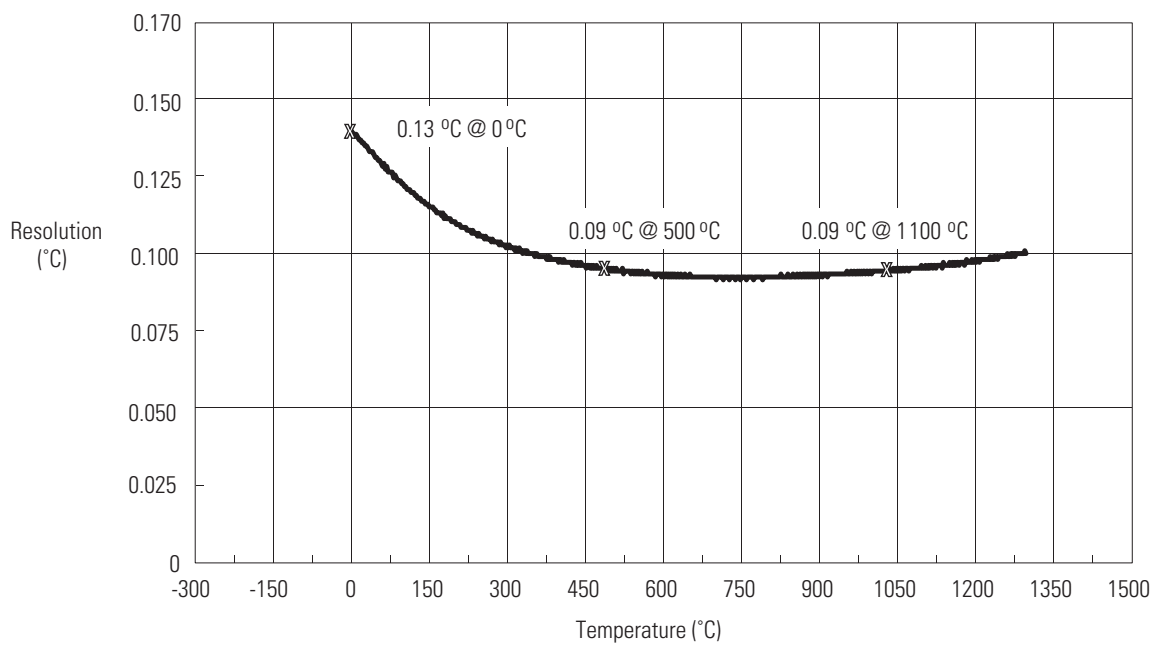
Type E Thermocouple**Type R Thermocouple**

Type S Thermocouple



Type T Thermocouple



Type B Thermocouple**Type N Thermocouple**

Channel Configuration Worksheets

Select your bit configurations. Write them down at the bottom of the worksheet. Use one worksheet for each channel.

Channel Configuration Word (0:e.0 through 0:e.3) — Bit Descriptions

Bit or Bits	Define	To Select	Set these bits in the Channel Configuration Word												Description	
			15...12	11	10	9	8	7	6	5	4	3	2	1		0
0...3	Input Type	TC Type J										0	0	0	0	Project _____ Slot Number _____ Channel Number _____ Configure the channel for the input type connected to it. Valid inputs are thermocouples and analog input signals of ±50 mV and ±100 mV. You can configure the channel to read the cold-junction (CJC) temperature. When reading the CJC temperature, the channel ignores the physical input signal.
		TC Type K										0	0	0	1	
		TC Type T										0	0	1	0	
		TC Type E										0	0	1	1	
		TC Type R										0	1	0	0	
		TC Type S										0	1	0	1	
		TC Type B										0	1	1	0	
		TC Type N										0	1	1	1	
		±50 mV										1	0	0	0	
		±100 mV										1	0	0	1	
		TC Type C										1	0	1	0	
		TC Type D										1	0	1	1	
		Invalid										1	1	0	0	
		Invalid										1	1	0	1	
		Invalid										1	1	1	0	
		CJC Temp										1	1	1	1	
4, 5	Data Format	Engr. Units x1								0	0					Select the channel data format from: Engineering units (EU) x1 or x10. For EU x1, values are in 0.1 degrees or 0.01 mV. For EU x10, values are in whole °C or °F or 0.1 mV. Scaled-for-PID (value is the same for any input type). Proportional input signal range is scaled to 0...16,383 counts. Proportional counts (value is same for any input type). Proportional input signal range is scaled to ±32,767 counts. For more information, refer to page 49.
		Engr. Units x10								0	1					
		Scaled-for-PID								1	0					
		Counts								1	1					

Channel Configuration Word (0:e.0 through 0:e.3) — Bit Descriptions (Continued)

Bit or Bits	Define	To Select	Set these bits in the Channel Configuration Word													Description
			15...12	11	10	9	8	7	6	5	4	3	2	1	0	
6, 7	Open-circuit Mode	Zero						0	0							Select module response to a detected open-circuit from: Zero to force the channel data word to zero. Upscale to force the channel data word to full scale. Downscale to force channel data word to low scale. Important: A bit selection or 1 1 is invalid. For an open CJC thermistor, mV channels are not affected. Important: The module requires 500 ms or one module update to flag the error while it ramps the channel input.
		Upscale						0	1							
		Downscale						1	0							
		Invalid						1	1							
8	Units °F, °C	Degrees C				0										Select °C/°F for thermal inputs. Ignored for mV inputs. Important: For EU x1 and °F (0.1 °F), an over-range error will occur above 3276.7 °F (cannot exceed 32,767 counts).
		Degrees F				1										
9, 10	Unused	Unused			0	0										These bits must be zero for a valid configuration.
11	Chnl Enable	Channel Off		0												Disable unused channels for faster response. When set, the module configures the channel and reads the channel input before setting bit 11 in the status word. If you change the configuration word, the status word must reflect the change before new data is valid. If you clear the configuration word, the module clears channel and status words. For a new configuration word, channel data and status words remain cleared until the module sets this bit (11) in the status word.
		Channel On		1												
12...15	Unused	Unused	0000													These bits must be zero for a valid configuration.
Enter Your Bit Selections >>			0000													For the Channel Configuration Word

Select your bit configurations. Write them down at the bottom of the worksheet. Use one worksheet for each channel.

Channel Configuration Word (0:e.0 through 0:e.3) — Bit Descriptions

Bit or Bits	Define	To Select	Set these bits in the Channel Configuration Word																Description
			15...12	11	10	9	8	7	6	5	4	3	2	1	0				
0...3	Input Type	TC Type J										0	0	0	0	Project _____ Slot Number _____ Channel Number _____ Configure the channel for the input type connected to it. Valid inputs are thermocouples and analog input signals of ±50 mV and ±100 mV. You can configure the channel to read the cold-junction (CJC) temperature. When reading the CJC temperature, the channel ignores the physical input signal.			
		TC Type K										0	0	0	1				
		TC Type T										0	0	1	0				
		TC Type E										0	0	1	1				
		TC Type R										0	1	0	0				
		TC Type S										0	1	0	1				
		TC Type B										0	1	1	0				
		TC Type N										0	1	1	1				
		±50 mV										1	0	0	0				
		±100 mV										1	0	0	1				
		TC Type C										1	0	1	0				
		TC Type D										1	0	1	1				
		Invalid										1	1	0	0				
		Invalid										1	1	0	1				
		Invalid										1	1	1	0				
		CJC Temp										1	1	1	1				
4, 5	Data Format	Engr. Units x1								0	0					Select the channel data format from: Engineering units (EU) x1 or x10. For EU x1, values are in 0.1 degrees or 0.01 mV. For EU x10, values are in whole °C or °F or 0.1 mV. Scaled-for-PID (value is the same for any input type). Proportional input signal range is scaled to 0...16,383 counts. Proportional counts (value is same for any input type). Proportional input signal range is scaled to ±32,767 counts. For more information, refer to page 49.			
		Engr. Units x10								0	1								
		Scaled-for-PID								1	0								
		Counts								1	1								
6, 7	Open-circuit Mode	Zero						0	0							Select module response to a detected open-circuit from: Zero to force the channel data word to zero. Upscale to force the channel data word to full scale. Downscale to force channel data word to low scale. Important: A bit selection or 1 1 is invalid. For an open CJC thermistor, mV channels are not affected. Important: The module requires 500 ms or one module update to flag the error while it ramps the channel input.			
		Upscale						0	1										
		Downscale						1	0										
		Invalid						1	1										

Channel Configuration Word (0:e.0 through 0:e.3) — Bit Descriptions (Continued)

Bit or Bits	Define	To Select	Set these bits in the Channel Configuration Word													Description
			15...12	11	10	9	8	7	6	5	4	3	2	1	0	
8	Units °F, °C	Degrees C				0										Select °C/°F for thermal inputs. Ignored for mV inputs. Important: For EU x1 and °F (0.1 °F), an over-range error will occur above 3276.7 °F (cannot exceed 32,767 counts).
		Degrees F				1										
9, 10	Unused	Unused			0	0										These bits must be zero for a valid configuration.
11	Chnl Enable	Channel Off		0												Disable unused channels for faster response. When set, the module configures the channel and reads the channel input before setting bit 11 in the status word. If you change the configuration word, the status word must reflect the change before new data is valid. If you clear the configuration word, the module clears channel and status words. For a new configuration word, channel data and status words remain cleared until the module sets this bit (11) in the status word.
		Channel On		1												
12...15	Unused	Unused	0000													These bits must be zero for a valid configuration.
Enter Your Bit Selections >>			0000													For the Channel Configuration Word

Select your bit configurations. Write them down at the bottom of the worksheet. Use one worksheet for each channel.

Channel Configuration Word (0:e.0 through 0:e.3) — Bit Descriptions

Bit or Bits	Define	To Select	Set these bits in the Channel Configuration Word																Description
			15...12	11	10	9	8	7	6	5	4	3	2	1	0				
0...3	Input Type	TC Type J										0	0	0	0	Project _____ Slot Number _____ Channel Number _____ Configure the channel for the input type connected to it. Valid inputs are thermocouples and analog input signals of ±50 mV and ±100 mV. You can configure the channel to read the cold-junction (CJC) temperature. When reading the CJC temperature, the channel ignores the physical input signal.			
		TC Type K										0	0	0	1				
		TC Type T										0	0	1	0				
		TC Type E										0	0	1	1				
		TC Type R										0	1	0	0				
		TC Type S										0	1	0	1				
		TC Type B										0	1	1	0				
		TC Type N										0	1	1	1				
		±50 mV										1	0	0	0				
		±100 mV										1	0	0	1				
		TC Type C										1	0	1	0				
		TC Type D										1	0	1	1				
		Invalid										1	1	0	0				
		Invalid										1	1	0	1				
		Invalid										1	1	1	0				
		CJC Temp										1	1	1	1				
4, 5	Data Format	Engr. Units x1								0	0					Select the channel data format from: Engineering units (EU) x1 or x10. For EU x1, values are in 0.1 degrees or 0.01 mV. For EU x10, values are in whole °C or °F or 0.1 mV. Scaled-for-PID (value is the same for any input type). Proportional input signal range is scaled to 0...16,383 counts. Proportional counts (value is same for any input type). Proportional input signal range is scaled to ±32,767 counts. For more information, refer to page 49.			
		Engr. Units x10								0	1								
		Scaled-for-PID								1	0								
		Counts								1	1								
6, 7	Open-circuit Mode	Zero						0	0							Select module response to a detected open-circuit from: Zero to force the channel data word to zero. Upscale to force the channel data word to full scale. Downscale to force channel data word to low scale. Important: A bit selection or 1 1 is invalid. For an open CJC thermistor, mV channels are not affected. Important: The module requires 500 ms or one module update to flag the error while it ramps the channel input.			
		Upscale						0	1										
		Downscale							1	0									
		Invalid							1	1									

Channel Configuration Word (0:e.0 through 0:e.3) — Bit Descriptions (Continued)

Bit or Bits	Define	To Select	Set these bits in the Channel Configuration Word													Description
			15...12	11	10	9	8	7	6	5	4	3	2	1	0	
8	Units °F, °C	Degrees C				0										Select °C/°F for thermal inputs. Ignored for mV inputs. Important: For EU x1 and °F (0.1 °F), an over-range error will occur above 3276.7 °F (cannot exceed 32,767 counts).
		Degrees F				1										
9, 10	Unused	Unused			0	0										These bits must be zero for a valid configuration.
11	Chnl Enable	Channel Off		0												Disable unused channels for faster response. When set, the module configures the channel and reads the channel input before setting bit 11 in the status word. If you change the configuration word, the status word must reflect the change before new data is valid. If you clear the configuration word, the module clears channel and status words. For a new configuration word, channel data and status words remain cleared until the module sets this bit (11) in the status word.
		Channel On		1												
12...15	Unused	Unused	0000													These bits must be zero for a valid configuration.
Enter Your Bit Selections >>			0000													For the Channel Configuration Word

Select your bit configurations. Write them down at the bottom of the worksheet. Use one worksheet for each channel.

Channel Configuration Word (0:e.0 through 0:e.3) — Bit Descriptions

Bit or Bits	Define	To Select	Set these bits in the Channel Configuration Word																Description
			15...12	11	10	9	8	7	6	5	4	3	2	1	0				
0...3	Input Type	TC Type J										0	0	0	0	Project _____ Slot Number _____ Channel Number _____ Configure the channel for the input type connected to it. Valid inputs are thermocouples and analog input signals of ±50 mV and ±100 mV. You can configure the channel to read the cold-junction (CJC) temperature. When reading the CJC temperature, the channel ignores the physical input signal.			
		TC Type K										0	0	0	1				
		TC Type T										0	0	1	0				
		TC Type E										0	0	1	1				
		TC Type R										0	1	0	0				
		TC Type S										0	1	0	1				
		TC Type B										0	1	1	0				
		TC Type N										0	1	1	1				
		±50 mV										1	0	0	0				
		±100 mV										1	0	0	1				
		TC Type C										1	0	1	0				
		TC Type D										1	0	1	1				
		Invalid										1	1	0	0				
		Invalid										1	1	0	1				
		Invalid										1	1	1	0				
		CJC Temp										1	1	1	1				
4, 5	Data Format	Engr. Units x1								0	0					Select the channel data format from: Engineering units (EU) x1 or x10. For EU x1, values are in 0.1 degrees or 0.01 mV. For EU x10, values are in whole °C or °F or 0.1 mV. Scaled-for-PID (value is the same for any input type). Proportional input signal range is scaled to 0...16,383 counts. Proportional counts (value is same for any input type). Proportional input signal range is scaled to ±32,767 counts. For more information, refer to page 49.			
		Engr. Units x10								0	1								
		Scaled-for-PID								1	0								
		Counts								1	1								
6, 7	Open-circuit Mode	Zero						0	0							Select module response to a detected open-circuit from: Zero to force the channel data word to zero. Upscale to force the channel data word to full scale. Downscale to force channel data word to low scale. Important: A bit selection or 1 1 is invalid. For an open CJC thermistor, mV channels are not affected. Important: The module requires 500 ms or one module update to flag the error while it ramps the channel input.			
		Upscale						0	1										
		Downscale						1	0										
		Invalid						1	1										

Channel Configuration Word (0:e.0 through 0:e.3) — Bit Descriptions (Continued)

Bit or Bits	Define	To Select	Set these bits in the Channel Configuration Word													Description
			15...12	11	10	9	8	7	6	5	4	3	2	1	0	
8	Units °F, °C	Degrees C				0										Select °C/°F for thermal inputs. Ignored for mV inputs. Important: For EU x1 and °F (0.1 °F), an over-range error will occur above 3276.7 °F (cannot exceed 32,767 counts).
		Degrees F				1										
9, 10	Unused	Unused			0	0										These bits must be zero for a valid configuration.
11	Chnl Enable	Channel Off		0												Disable unused channels for faster response. When set, the module configures the channel and reads the channel input before setting bit 11 in the status word. If you change the configuration word, the status word must reflect the change before new data is valid. If you clear the configuration word, the module clears channel and status words. For a new configuration word, channel data and status words remain cleared until the module sets this bit (11) in the status word.
		Channel On		1												
12...15	Unused	Unused	0000													These bits must be zero for a valid configuration.
Enter Your Bit Selections >>			0000													For the Channel Configuration Word

Thermocouple Descriptions

The descriptions of thermocouples J, K, T, E, R, and S were extracted from NBS Monograph 125 (ITS-68) issued March 1974. We also describe types C and D.

J Type Thermocouple (iron versus copper-nickel <Constantan⁽¹⁾>)

The J thermocouple is the least suitable for accurate thermometry because there are significant nonlinear deviations in the thermoelectric output from different manufacturers. The total and specific types of impurities that occur in commercial iron change with time, location of primary ores, and methods of smelting.

Type J thermocouples are recommended by the ASTM [1970] for use in the temperature range from 0...760 °C (32...1400 °F) in vacuum, oxidizing, reducing or inert atmospheres. If used for extended times above 500 °C (932 °F), heavy gauge wires are recommended because the oxidation rate is rapid at elevated temperatures.

They should not be used in sulfurous atmospheres above 500 °C (932 °F). Because of potential rusting and embrittlement, they are not recommended for subzero temperatures. They should not be cycled above 760 °C (1400 °F) even for a short time if accurate readings below 760 °C (1400 °F) are desired at a later time.

The negative thermoelement, a copper-nickel alloy, is subject to substantial composition changes under thermal neutron irradiation, since copper is converted to nickel and zinc.

Commercial iron undergoes a magnetic transformation near 769 °C (1416 °F) and <an alpha – gamma> crystal transformation near 910 °C (1670 °F). Both of these transformations, especially the latter, seriously affect the thermoelectric properties of iron, and therefore, the Type J thermocouples. If Type J thermocouples are taken to high temperatures, especially above 900 °C (1652 °F), they will lose accuracy of their calibration when they are recycled to lower temperatures.

⁽¹⁾ It should be noted that the Constantan element of Type J thermoelements is not interchangeable with the Constantan element of Types T or N due to the different ration of copper and nickel in each.

ASTM Standard E230-72 in the Annual Book of ASTM Standards [1972] specifies that the standard limits of error for Type J commercial thermocouples be ± 2.2 °C (± 35.9 °F) between 0...277 °C (32...531 °F) and $\pm 3/4\%$ between 277...760 °C (531...1400 °F). Limits of error are not specified for Type J thermocouples below 0 °C (32 °F) or above 760 °C (1400 °F). Type J thermocouples can also be supplied to meet special limits of error, which are equal to one half the limits given above.

The recommended upper temperature limit for protected thermocouples, 760 °C (1400 °F), applies to 3.3mm (8 AWG) wire. For smaller wires, the recommended upper temperature decreases to 593 °C (1099 °F) for 1.6mm (14 AWG), and 371 °C (700 °F) for 0.5 or 0.3mm (24 or 28 AWG)."

K Type Thermocouple (nickel-chromium versus nickel-aluminum)

This type is more resistant to oxidation at elevated temperatures than the Types E, J, or T thermocouples and consequently it finds wide application at temperatures above 500 °C (932 °F).

Type K thermocouples may be used at liquid hydrogen temperatures. However, their Seebeck coefficient (about 4 uV/K at 20 k) is only about one-half of that of E thermocouples. Furthermore, the thermoelectric homogeneity of KN thermoelements is generally not quite as good as that of EN thermoelements. Both the KP and the KN thermoelements do have a relatively low thermal conductivity and good resistance to corrosion in moist atmospheres at low temperatures.

Type K thermocouples are recommended by the ASTM [1970] for continuous use at temperatures within the range -250...1260 °C (-418...2300 °F) in oxidizing or inert atmospheres. Both the KP and the KN thermoelements are subject to oxidation when used in air above about 850 °C (1562 °F), but even so, Type K thermocouples may be used at temperatures up to about 1350 °C (2462 °F) for short periods with only small changes in calibration.

They should not be used in sulfurous, reducing, or alternately reducing and oxidizing atmospheres unless suitably protected with protecting tubes. They should not be used in vacuum (at high temperatures) for extended times because the chromium in the positive thermoelement vaporizes out of solution and alters the calibration. They should also not be used in atmospheres that promote green-rot corrosion (those with low, but not negligible, oxygen content).

ASTM Standard E230-72 in the Annual Book of ASTM Standards [1972] specifies that the standard limits of error for Type K commercial thermocouples be $\pm 2.2\text{ }^{\circ}\text{C}$ ($\pm 35.9\text{ }^{\circ}\text{F}$) between $0\text{...}277\text{ }^{\circ}\text{C}$ ($32\text{...}530.6\text{ }^{\circ}\text{F}$) and $\pm 3/4\%$ between $277\text{...}1260\text{ }^{\circ}\text{C}$ ($530.6\text{...}2300\text{ }^{\circ}\text{F}$). Limits of error are not specified for the Type K thermocouples below $0\text{ }^{\circ}\text{C}$ ($32\text{ }^{\circ}\text{F}$). Type K thermocouples can also be supplied to meet special limits of error, which are equal to one half the standard limits of error given above. The recommended upper temperature limit for protected Type K thermocouples, $1260\text{ }^{\circ}\text{C}$ ($2300\text{ }^{\circ}\text{F}$), applies for 3.3 mm (8 AWG) wire. For smaller wires, it decreases to $1093\text{ }^{\circ}\text{C}$ ($2000\text{ }^{\circ}\text{F}$) for 1.6 mm (14 AWG), $982\text{ }^{\circ}\text{C}$ ($1800\text{ }^{\circ}\text{F}$) for 0.8 mm (20 AWG), and $871\text{ }^{\circ}\text{C}$ ($1600\text{ }^{\circ}\text{F}$) for 0.5 or 0.3 mm (24 or 28 AWG).

T Type Thermocouple (copper versus copper-nickel <Constantan⁽¹⁾>)

The homogeneity of most Type TP and TN (or EN) thermoelements is reasonably good. However, the Seebeck coefficient of Type T thermocouples is moderately small at subzero temperatures (about $5.6\text{ }\mu\text{V/K}$ at 20 K), being roughly two-thirds that of Type E thermocouples. This, together with the high thermal conductivity of Type TP thermoelements, is the major reason why Type T thermocouples are less suitable for use in the subzero range than Type E thermocouples.

Type T thermocouples are recommended by the ASTM [1970] for use in the temperature range $-184\text{...}371\text{ }^{\circ}\text{C}$ ($-300\text{...}700\text{ }^{\circ}\text{F}$) in vacuum or in oxidizing, reducing or inert atmospheres. The recommended upper temperature limit for continuous service of protected Type T thermocouples is set at $371\text{ }^{\circ}\text{C}$ ($700\text{ }^{\circ}\text{F}$) for 1.6 mm (14 AWG) thermoelements, since Type TP thermoelements oxidize rapidly above this temperature. However, the thermoelectric properties of Type TP thermoelements are apparently not grossly affected by oxidation since Roeser and Dahl [1938] observed negligible changes in the thermoelectric voltage of Nos. 12, 18, and 22 AWG Type TP thermoelements after heating for 30 hours in air at $500\text{ }^{\circ}\text{C}$ ($932\text{ }^{\circ}\text{F}$). At this temperature, the Type TN thermoelements have good resistance to oxidation and exhibit only small changes in thermal emf with long exposure in air, as shown by the studies of Dahl [1941]. Operation of Type T thermocouples in hydrogen atmospheres at temperatures above about $370\text{ }^{\circ}\text{C}$ ($698\text{ }^{\circ}\text{F}$) is not recommended since severe embrittlement of the Type TP thermoelements may occur.

⁽¹⁾ It should be noted that the Constantan element of Type J thermoelements is not interchangeable with the Constantan element of Types T or N due to the different ration of copper and nickel in each.

Type T thermoelements are not well suited for use in nuclear environments, since both thermoelements are subject to significant changes in composition under thermal neutron irradiation. The copper in the thermoelement is converted to nickel and zinc.

Because of the high thermal conductivity of Type TP thermoelements, special care should be exercised in the use of the thermocouples to insure that both the measuring and reference junctions assume the desired temperatures.

ASTM Standard E230-72 in the Annual Book of ASTM Standards [1972] specifies that the standard limits of error for Type T commercial thermocouples be $\pm 2\%$ between $-101 \dots -59$ °C ($-149.8 \dots -74.2$ °F), ± 0.8 °C (± 33.4 °F) between $-59 \dots 93$ °C ($-74 \dots 200$ °F), and $\pm 3/4\%$ between $93 \dots 371$ °C ($200 \dots 700$ °F). Type T thermocouples can also be supplied to meet special limits of error, which are equal to one half the standard limits of error given above (plus a limit of error of $\pm 1\%$ is specified between $-184 \dots -59$ °C ($-300 \dots -74$ °F). The recommended upper temperature limit for protected Type T thermocouples, 371 °C (700 °F), applies to 1.6mm (14 AWG) wire. For smaller wires, it decreases to 260 °C (500 °F) for 0.8mm (20 AWG) and 240 °C (464 °F) for 0.5 or 0.3mm (24 or 28 AWG)."

E Type Thermocouple (nickel-chromium versus copper-nickel <Constantan⁽¹⁾>)

Type E thermocouples are recommended by the ASTM Manual [1970] for use in the temperature range from $-250 \dots 871$ °C ($-418 \dots 1600$ °F) in oxidizing or inert atmospheres. The negative thermoelement is subject to deterioration above about 871 °C (1600 °F), but the thermocouple may be used up to 1000 °C (1832 °F) for short periods.

The ASTM Manual [1970] indicates the following restrictions at high temperatures. They should not be used in sulfurous, reducing or alternately reducing and oxidizing atmospheres unless suitably protected with protecting tubes. They should not be used in vacuum (at high temperatures) for extended times, because the chromium in the positive thermoelement vaporizes out of solution and alters the calibration. They should also not be used in atmospheres that promote green-rot corrosion (those with low, but not negligible, oxygen content).

The negative thermoelement, a copper-nickel alloy, is subject to composition changes under thermal neutron irradiation since the copper is converted to nickel and zinc.

⁽¹⁾ It should be noted that the Constantan element of Type J thermoelements is not interchangeable with the Constantan element of Types T or N due to the different ration of copper and nickel in each.

ASTM Standard E230-72 in the Annual Book of ASTM Standards [1972] specifies that the standard limits of error for the Type E commercial thermocouples be $\pm 1.7\text{ }^{\circ}\text{C}$ ($\pm 35\text{ }^{\circ}\text{F}$) between $0\text{...}316\text{ }^{\circ}\text{C}$ ($32\text{...}600\text{ }^{\circ}\text{F}$) and $\pm 1/2\%$ between $316\text{...}871\text{ }^{\circ}\text{C}$ ($600\text{...}1600\text{ }^{\circ}\text{F}$). Limits of error are not specified for Type E thermocouples below $0\text{ }^{\circ}\text{C}$ ($32\text{ }^{\circ}\text{F}$). Type E thermocouples can also be supplied to meet special limits of error, which are less than the standard limits of error given above $\pm 1.25\text{ }^{\circ}\text{C}$ ($\pm 34.3\text{ }^{\circ}\text{F}$) between $0\text{...}316\text{ }^{\circ}\text{C}$ ($32\text{...}600\text{ }^{\circ}\text{F}$) and $\pm 3/8\%$ between $316\text{...}871\text{ }^{\circ}\text{C}$ ($600\text{...}1600\text{ }^{\circ}\text{F}$), applies to 3.3mm (8 AWG) wire. For smaller wires, the recommended upper temperature decreases to $649\text{ }^{\circ}\text{C}$ ($1200\text{ }^{\circ}\text{F}$) for 1.6mm (14 AWG), $538\text{ }^{\circ}\text{C}$ ($1000\text{ }^{\circ}\text{F}$) for 0.8mm (20 AWG) and $427\text{ }^{\circ}\text{C}$ ($800\text{ }^{\circ}\text{F}$) for 0.5 or 0.3mm (24 or AWG).

**S and R Type Thermocouple
S (platinum-10% rhodium
versus platinum)
R (platinum-13% rhodium
versus platinum)**

The ASTM manual STP 470 [1970] indicates the following restrictions on the use of S and R type thermocouples at high temperatures. They should not be used in reducing atmospheres, nor in those containing metallic vapor (such as lead or zinc), nonmetallic vapors (such as arsenic, phosphorous, or sulfur) or easily reduced oxides, unless suitably protected with nonmetallic protecting tubes. They should never be inserted directly into a metallic primary tube.

The positive thermoelement, platinum-10% rhodium (13% rhodium for R), is unstable in a thermal neutron flux because the rhodium converts to palladium. The negative thermoelement, pure platinum, is relatively stable to neutron transmutation. However, fast neutron bombardment will cause physical damage, which changes the thermoelectric voltage unless it is annealed out.

The thermoelectric voltages of platinum based thermocouples are sensitive to their heat treatments. In particular, quenching from high temperatures should be avoided.

ASTM Standard E230-72 in the Annual Book of ASTM Standards [1972] specifies that the standard limits of error for Type S and R commercial thermocouples be $\pm 1.4\text{ }^{\circ}\text{C}$ ($\pm 34.5\text{ }^{\circ}\text{F}$) between $0\text{...}538\text{ }^{\circ}\text{C}$ ($32\text{...}1000\text{ }^{\circ}\text{F}$) and $\pm 1/4\%$ between $538\text{...}1482\text{ }^{\circ}\text{C}$ ($1000\text{...}2700\text{ }^{\circ}\text{F}$). Limits of error are not specified for Type S (or R) thermocouples below $0\text{ }^{\circ}\text{C}$ ($32\text{ }^{\circ}\text{F}$). The recommended upper temperature limit for continuous use of protected thermocouples, $1482\text{ }^{\circ}\text{C}$ ($2700\text{ }^{\circ}\text{F}$), applies to 0.5mm (24 AWG) wire.

C and D Type Thermocouples

C (tungsten-5% rhenium versus tungsten-26% rhenium)

D (tungsten-3% rhenium versus tungsten-25% rhenium)

Types C and D thermocouples are recommended for use in the temperature range from 0...2320 °C (32...4208 °F) in non-oxidizing inert atmospheres. They are not practical for use below 399 °C (750 °F). Beware of embrittlement.

C and D Thermocouple Recommended Use

Code	Color Code	Max Useful Temp. Range	EMF Over Useful Range	Std. Limits of Error
C	Jacket: wht-red trace + = wht, - = red	TC grade: 0...2320 °C (32...4208 °F) Ext grade: 0...870 °C (32...1600 °F)	0...37.066 mV	4.5...450 °C (40.1...842 °F) 1.0% to 2320 °C (4208 °F)
D	Jacket: wht-yel trace + = wht, - = red	TC grade: 0...2320 °C (32...4208 °F) Ext grade: 0...260 °C (32...500 °F)	0...39.506 mV	4.5...450 °C (40.1...842 °F) 1.0% to 2320 °C (4208 °F)

Channel Calibration

This appendix shows you how to calibrate the module's input channels.

About the Procedure

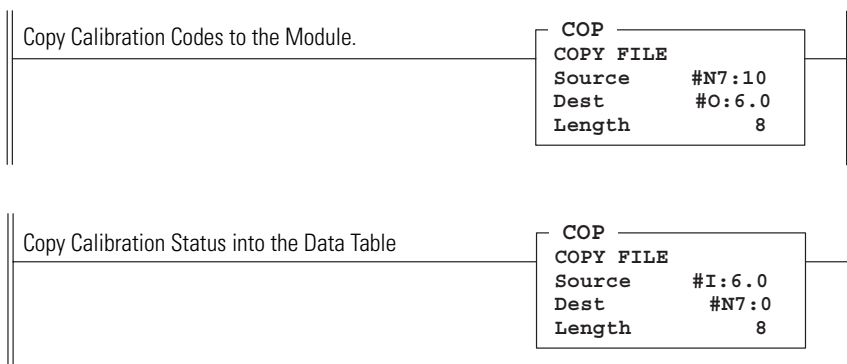
The purpose of the procedure is to store a pair of calibration values in EEPROM for each channel to set channel accuracy at 0.05% of full range regardless of channel circuit tolerances. The module is designed so you can calibrate its input channels individually or in groups. The thermocouple/mV operation of all channels is suspended during calibration.

With your programming terminal, you enter calibration codes in word 5 of the configuration file and read status in words 4 and 5 of the status file. A rung of ladder logic copies calibration codes into the output image table for transfer to the module, and another rung copies calibration status from the module (input image table) into the data table. You perform calibration with the SLC processor in Run mode.

For more information on addressing calibration words, refer to Chapter 4.

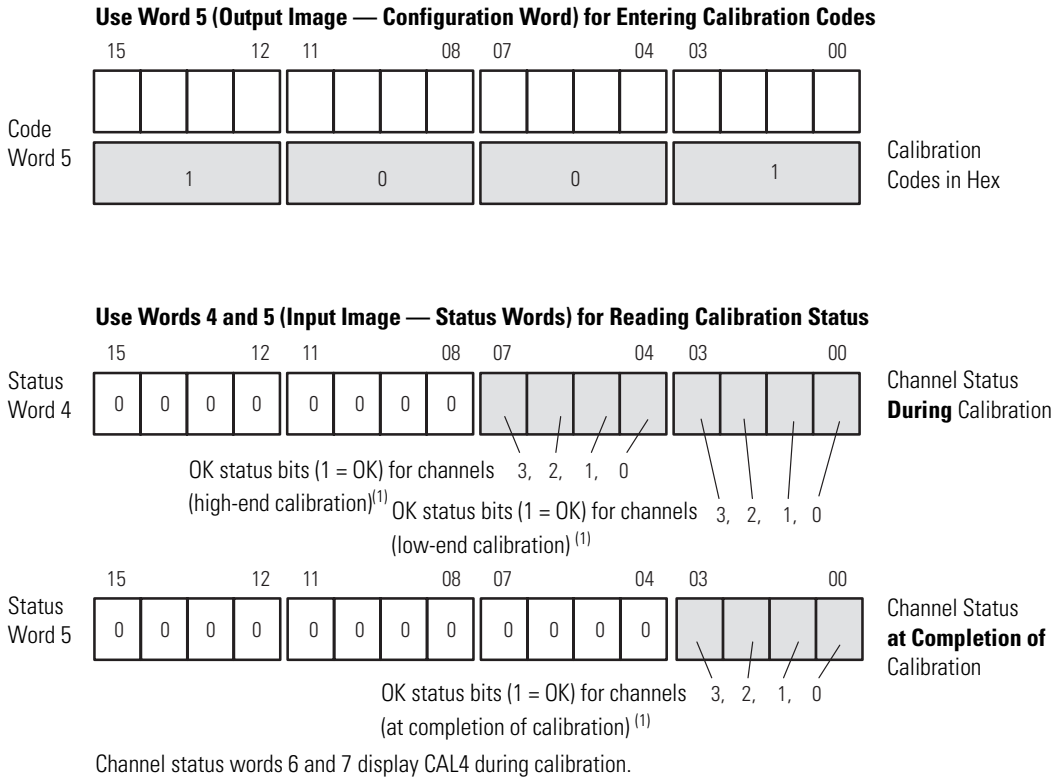
Calibration Logic

Before starting the procedure, enter the following calibration rungs into processor memory.



Calibration Codes and Status

Use the following format for entering calibration code words and reading calibration status bits. You enter calibration values in Hex. You can read channel status OK bits at different steps in the calibration procedure, one bit for each channel you are calibrating.



(1) Reads F Hex if all four channels are OK.

Calibration Procedure

To perform this calibration procedure, you need a precision dc voltmeter and precision power supply that displays and maintains a calibration voltage to 1/1000 of a millivolt: at 0.000 mV and 90.000 mV.

Prepare for calibration by removing the thermocouple leads from the input terminals of the channels that you want to calibrate. Switch the SLC processor to Run mode so it can execute the calibration ladder logic. For convenience, we suggest that you calibrate all four channels at the same time.

1. With your programming terminal, enter calibration code 1001 Hex into the data table address for configuration word 5.

2. Observe status words 0...3, 6 and 7.

The module returns the code CAL4 Hex in status words 6 and 7. It also clears channel data words 0...3.

3. Short circuit the pairs of input terminals for the channels you want to calibrate.

Make the jumper as short as possible.

4. With your programming terminal, enter calibration code 1002 Hex into the data table address for configuration word 5.

5. Observe bits 0...3 in status word 4.

If all the channels you are calibrating see zero voltage, the module returns status-OK bits set, one bit for each channel (F Hex for all four channels). Otherwise, the module returns channel status bits set to zero.

6. Apply 90.000 mV to the pairs of input terminals, all in parallel, for the channels you are calibrating.

Make your leads as short as possible.

7. With your programming terminal, enter calibration code 1004 Hex into the data table address for configuration word 5.

8. Observe bits 4...7 in status word 4.

If all the channels you are calibrating see 90.000 mV, the module returns status-OK bits set, one bit for each channel (F Hex for all four channels). Otherwise, the module returns channel status bits set to zero.

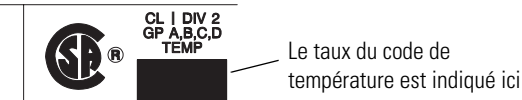
9. Remove the 90.000 mV calibration voltage.
10. With your programming terminal, enter calibration code 1008 Hex into the data table address for configuration word 5.
11. Observe bits 0...3 in status word 5.

After the module burns the calibration values into its EEPROM, it returns status-OK bits set, one bit for each channel (F Hex for all four channels). If the module could not complete the calibration of one or more channels, it returns a zeroed status bit for that channel (non-F Hex returned).

12. To end the calibration procedure, enter calibration code 0000 Hex into the data table address for configuration word 5 with your programming terminal.

During thermocouple/mV module operation, word 5 must be zero.

CSA Hazardous Location Approval

CSA Hazardous Location Approval	Approbation d'utilisation dans des emplacements dangereux par la CSA
CSA certifies products for general use as well as for use in hazardous locations. Actual CSA certification is indicated by the product label as shown below, and not by statements in any user documentation.	La CSA certifie les produits d'utilisation générale aussi bien que ceux qui s'utilisent dans des emplacements dangereux. La certification CSA en vigueur est indiquée par l'étiquette du produit et non par des affirmations dans la documentation à l'usage des utilisateurs.
Example of the CSA certification product label 	Exemple d'étiquette de certification d'un produit par la CSA 
To comply with CSA certification for use in hazardous locations, the following information becomes a part of the product literature for CSA-certified Allen-Bradley industrial control products. • This equipment is suitable for use in Class I, Division 2, Groups A, B, C, D, or nonhazardous locations only. • The products having the appropriate CSA markings (that is, Class I, Division 2, Groups A, B, C, D), are certified for use in other equipment where the suitability of combination (that is, application or use) is determined by the CSA or the local inspection office having jurisdiction.	Pour satisfaire à la certification de la CSA dans des endroits dangereux, les informations suivantes font partie intégrante de la documentation des produits industriels de contrôle Allen-Bradley certifiés par la CSA. • Cet équipement convient à l'utilisation dans des emplacements de Classe I, Division 2, Groupes A, B, C, D, ou ne convient qu'à l'utilisation dans des endroits non dangereux. • Les produits portant le marquage approprié de la CSA (c'est à dire, Classe I, Division 2, Groupes A, B, C, D) sont certifiés à l'utilisation pour d'autres équipements où la convenance de combinaison (application ou utilisation) est déterminée par la CSA ou le bureau local d'inspection qualifié.
Important: Due to the modular nature of a PLC control system, the product with the highest temperature rating determines the overall temperature code rating of a PLC control system in a Class I, Division 2 location. The temperature code rating is marked on the product label as shown.	Important: Par suite de la nature modulaire du système de contrôle PLC, le produit ayant le taux le plus élevé de température détermine le taux d'ensemble du code de température du système de contrôle d'un PLC dans un emplacement de Classe I, Division 2. Le taux du code de température est indiqué sur l'étiquette du produit.
Temperature code rating 	Taux du code de température 

CSA Hazardous Location Approval	Approbation d'utilisation dans des emplacements dangereux par la CSA
The following warnings apply to products having CSA certification for use in hazardous locations.	Les avertissements suivants s'appliquent aux produits ayant la certification CSA pour leur utilisation dans des emplacements dangereux.
ATTENTION Explosion hazard — • Substitution of components may impair suitability for Class I, Division 2. • Do not replace components unless power has been switched off or the area is known to be nonhazardous. • Do not disconnect equipment unless power has been switched off or the area is known to be nonhazardous. • Do not disconnect connectors unless power has been switched off or the area is known to be nonhazardous. Secure any user-supplied connectors that mate to external circuits on an Allen-Bradley product using screws, sliding latches, threaded connectors, or other means such that any connection can withstand a 15 Nm (3.4 lb-in) separating force applied for a minimum of one minute.	AVERTISSEMENT Risque d'explosion — • La substitution de composants peut rendre ce matériel inacceptable pour les emplacements de Classe I, Division 2. • Couper le courant ou s'assurer que l'emplacement est désigné non dangereux avant de remplacer les composants. • Avant de débrancher l'équipement, couper le courant ou s'assurer que l'emplacement est désigné non dangereux. • Avant de débrancher les connecteurs, couper le courant ou s'assurer que l'emplacement est reconnu non dangereux. Attacher tous connecteurs fournis par l'utilisateur et reliés aux circuits externes d'un appareil Allen-Bradley à l'aide de vis, loquets coulissants, connecteurs filetés ou autres moyens permettant aux connexions de résister à une force de séparation de 15 Nm (3,4 lb-in – 1,5 kg) appliquée pendant au moins une minute.

Terms and Abbreviations

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

A/D

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

attenuation

The reduction in the magnitude of a signal as it passes through a system. The opposite of gain.

channel

Refers to one of four, small-signal analog input interfaces to the module's terminal block. Each channel is configured for connection to a thermocouple or dc millivolt (mV) input device, and has its own configuration and status words.

chassis

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

CJC (Cold Junction Compensation)

The means by which the module compensates for the offset voltage error introduced by the temperature at the junction between the thermocouple lead wire and the input terminal block (the cold junction).

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 signal induced in conductors with respect to ground (0 potential).

configuration word

Contains the channel configuration information needed by the module to configure and operate each channel. The module is designed for software rather than hardware configuration.

cut-off frequency

The frequency at which the input signal is attenuated 3 dB by the digital input filter. Frequency components of the input signal below the cut-off frequency are passed with under 3 dB of attenuation.

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 low-pass filter of the A/D converter. The digital filter provides high-frequency noise rejection.

effective resolution

The number of bits in the channel data word used to represent useful information.

full scale error (gain error)

The difference in slope between the actual and ideal analog/thermocouple transfer functions.

full scale range (FSR)

The difference between the maximum and minimum specified analog/thermocouple input values.

gain drift

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

input data scaling

Depends on the data format that you select for the channel data word. You can select from scaled-for-PID or Engineering Units for millivolt, thermocouple, or CJC inputs, which are automatically scaled. You may also select proportional counts, which you must compute to fit your application's temperature or voltage resolution.

local system

A control system with I/O chassis within several feet of the processor, and using 1746-C7 or 1746-C9 ribbon cable for communication.

LSB (least significant bit)

The bit that represents the smallest value within a string of bits. Refers to a data increment defined as the full scale range divided by the resolution.

multiplexer

A 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 electrical noise between differential inputs, but not between an input and ground or ground reference.

remote system

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 (for example 0.15 °C) or as a number of bits. For example, a 12-bit value has 4,096 possible counts. It can therefore be used to measure 1 part in 4096.

sampling time

The time for an A/D converter to sample an input channel.

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 module to process an input signal to reach 99.9% of its expected final value, given a large step change in the input signal.

update time

The time for the module to sample and convert a channel input signal and make the resulting value available to the SLC processor.

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Rockwell Automation Support

Rockwell Automation provides technical information on the Web to assist you in using its products. At <http://support.rockwellautomation.com>, you can find technical manuals, a knowledge base of FAQs, technical and application notes, sample code and links to software service packs, and a MySupport feature that you can customize to make the best use of these tools.

For an additional level of technical phone support for installation, configuration, and troubleshooting, we offer TechConnect Support programs. For more information, contact your local distributor or Rockwell Automation representative, or visit <http://support.rockwellautomation.com>.

Installation Assistance

If you experience a problem with a hardware module within the first 24 hours of installation, please review the information that's contained in this manual. You can also contact a special Customer Support number for initial help in getting your module up and running.

United States	1.440.646.3434 Monday – Friday, 8am – 5pm EST
Outside United States	Please contact your local Rockwell Automation representative for any technical support issues.

New Product Satisfaction Return

Rockwell tests all of its products to ensure that they are fully operational when shipped from the manufacturing facility. However, if your product is not functioning, it may need to be returned.

United States	Contact your distributor. You must provide a Customer Support case number (see phone number above to obtain one) to your distributor in order to complete the return process.
Outside United States	Please contact your local Rockwell Automation representative for return procedure.

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Publication 1746-UM614B-EN-P - September 2007

Supersedes Publication 1746-6.16 - January 1999

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