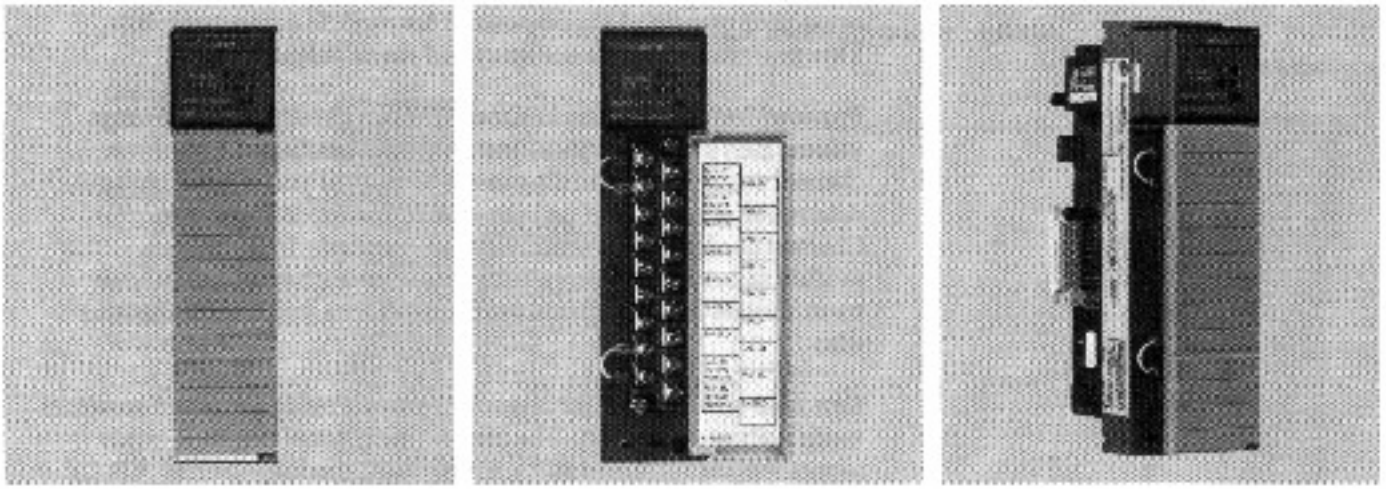
Rockwell Automation
Allen-Bradley

SLC 500™ Thermocouple/mV Input Module

(Catalog No. 1746-NT4)

Product Data



The NT4 Thermocouple/mV input module expands the present control capabilities of your SLC 500 fixed or modular system by allowing you to directly interface with any of eight types of thermocouple temperature sensors or with millivolt sensors such as strain gages. This greatly enhances the flexibility of SLC 500 applications by eliminating the need for expensive thermocouple transmitters, providing a more economical means of addressing process applications in industries requiring temperature measurement and control. It also provides the capability for accepting millivolt signals that are not within the application window of standard analog modules.

The NT4 module provides channel configuration flexibility that allows you to define the operational characteristics for each input channel on the module via your ladder logic programming. There are no hardware DIP switches to set. Each of the module's four channels is configured using your ladder program and may be dynamically reconfigured without handling the hardware. The NT4 performs on-board scaling to engineering units. You can specify thermocouple or millivolt operation, temperature resolution in degrees or tenths of degrees Celsius or Fahrenheit, or format conversion of the input data to proportional or scaled for PID.

Publication 1746-2.36 – March 1996

Features and Benefits

Provides a choice of four filter frequencies, permitting you to select input noise filtering appropriate to the application and surrounding environment. Either or both 50 Hz and 60 Hz noise can be filtered from the input signal for greater noise rejection and resolution. For applications such as injection molding, where system response speed is critical, minimum filtering (250 Hz) can be selected to reduce the time it takes a step change at the input to be made available to the SLC 500 controller.

Provides cold junction temperature compensation (CJC), fully integrated into the removable terminal block, as a means of retaining thermocouple input signal accuracy. Two thermistor assemblies located at each end of the terminal block measure and compensate for the absolute temperature of the reference junction.

Requires no user calibration. Each of the module's channels undergoes a calibration cycle at power-up, on channel configuration, or on your command to compensate for module component drift. This guarantees module accuracy and saves valuable time.

Provides fault diagnostics to check for open circuits or out-of-range values; then indicates operational problems on status LEDs. Four channel status LEDs and diagnostic bits signal you if input channel data is out of range or if an open-circuit condition is present. Channel configuration validity is also checked. In addition, a module status LED differentiates recoverable channel errors from more serious module-related problems, saving you troubleshooting time.

New 1746-NT4 Series B (or higher) modules provide increased common mode voltage separation. The channel-to-channel common-mode separation has increased to 2V for Series B modules (Series A is 0V separation). This ensures improved operation with multiple grounded thermocouples as long as the thermocouple ground potentials are within 2V of each other.

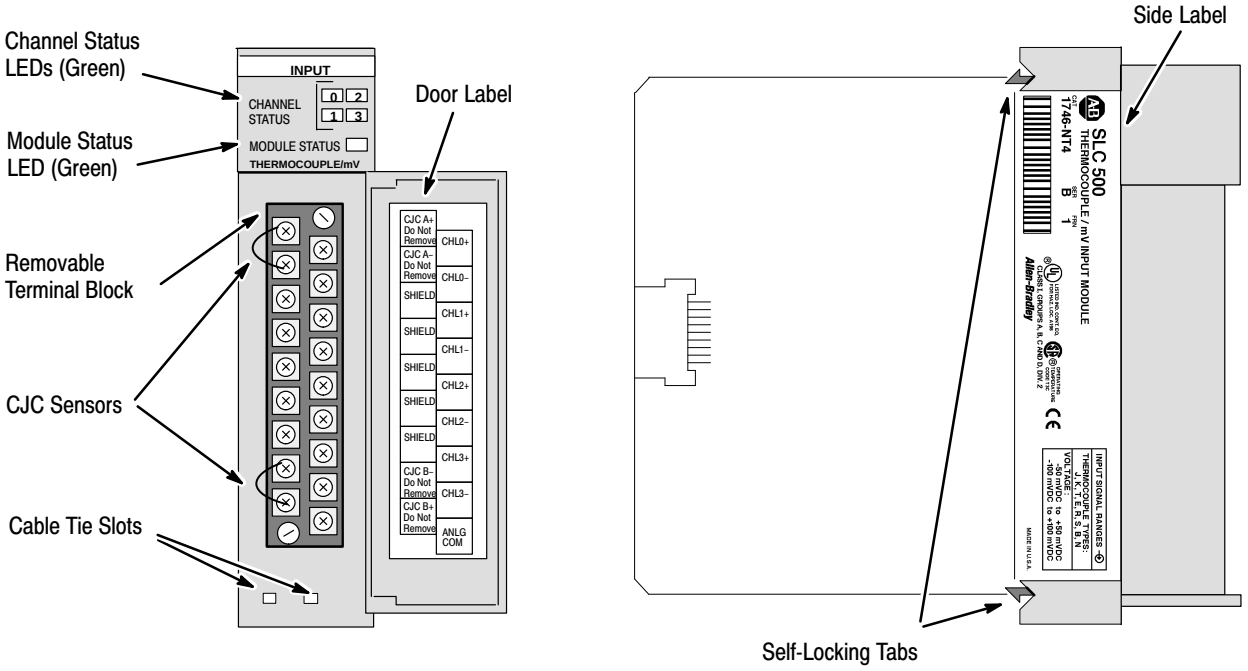
What's Inside...	Page

Hardware Overview

The thermocouple input module fits into any single slot, except the processor slot, of an SLC 500 modular system or an SLC 500 fixed system expansion chassis. It is a Class 1① module (uses 8 input and 8 output words) with 4 inputs multiplexed into a single A/D converter. It interfaces with up to 4 thermocouple types J, K, T, E, R, S, B, and N, and supports direct ±50 mV and ±100 mV analog input signals.

The module contains a removable terminal block providing connection for four thermocouple or DC millivolt analog input devices. There are also two cold-junction compensation (CJC) sensors used to compensate for offset voltages introduced into the thermocouple input signal as a result of the cold-junction, i.e., where the thermocouple wires connect to the module wiring terminal. There are no output channels on the module. Module configuration is done via your ladder program. There are no DIP switches.

① Requires use of Block Transfer in a remote configuration.



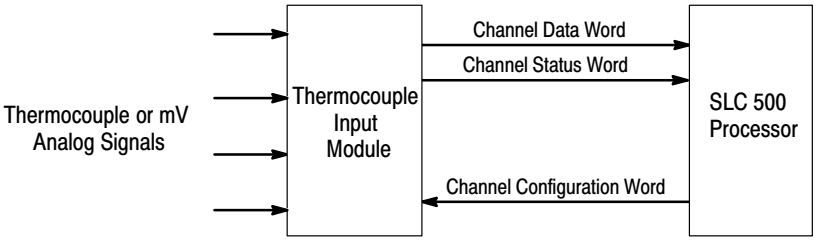
Hardware Features

Hardware	Function
Channel Status LED Indicators	Displays operating and fault status of channels 0, 1, 2, and 3
Module Status LED	Displays module operating and fault status
Side Label (Nameplate)	Provides module information
Removable Terminal Block	Provides physical connection to input devices. It is color coded green.
CJC Sensors	Compensate for offset voltages due to the cold junction
Door Label	Permits easy terminal identification
Cable Tie Slots	Secure and route wiring from module
Self-Locking Tabs	Secure module in chassis slot

Module Operation

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

After power-up checks are complete, the thermocouple module waits for valid channel configuration data from your SLC™ ladder logic program (channel status LEDs off). After configuration data is written to one or more channel configuration words and the module has done one conversion for each configured channel, the channel status LED goes on, and the thermocouple module continuously converts the thermocouple or millivolt input to a value within the range you selected (see page 9) for the enabled channels.



Each time a channel is read by the module, that data value is tested by the module for an under/over-range or open circuit condition. If such a condition is detected, an error bit is set in the channel status word and the appropriate channel LED blinks.

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. The processor and thermocouple module determine that the backplane data transfer was made without error, and the data is used in your ladder program.

Calibration

The thermocouple module is initially calibrated at the factory. The module also has an autocalibration function. Autocalibration compensates for offset and gain drift of the analog circuitry caused by temperature change within the module. An internal, high precision, low drift voltage reference and system ground are used for this purpose. Each of the module's channels undergoes a calibration cycle at power-up, on channel configuration or on your command. No external, user-supplied device is required for autocalibration.

Compatibility with Controllers and Thermocouple Sensors

The NT4 module is fully compatible with all SLC 500 fixed and modular controllers. It is compatible with all type J, K, T, E, R, S, B, and N thermocouple sensors and extension wire.

The NT4 uses the National Bureau of Standards (NBS) Monograph 125 and 161 (14 AWG Type N) based on IPTS–68 for thermocouple temperature linearization.

The following tables define thermocouple types and their associated temperature ranges and also list the millivolt analog input signal ranges that each channel will support.

Thermocouple Temperature Ranges

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

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

Millivolt Input Ranges

Millivolt Input Type	Range
±50 mV	–50 mV dc to +50 mV dc
±100 mV	–100 mV dc to +100 mV dc

Compatibility in a Fixed Expansion Chassis

The 2-slot, SLC 500 fixed I/O expansion chassis supports only specific combinations of modules. The table below summarizes compatibility. For complete compatibility information, refer to the SLC 500 Family System Overview (publication number 1747-2.30) or the Thermocouple/mV Input Module User Manual (publication number 1746-6.6.1).

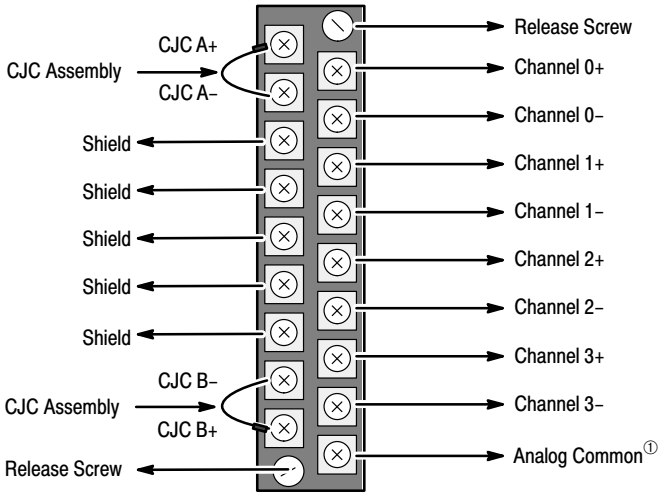
Fixed Chassis Compatibility

The NT4 module cannot be used with these modules:	The NT4 module can be used with this module and an External Power Supply:
OW16	NO4I
OB32	
OV32	

All combinations other than those listed above are valid.

Module Wiring

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



(Terminal Block Spare Part Catalog Number 1746-RT32)

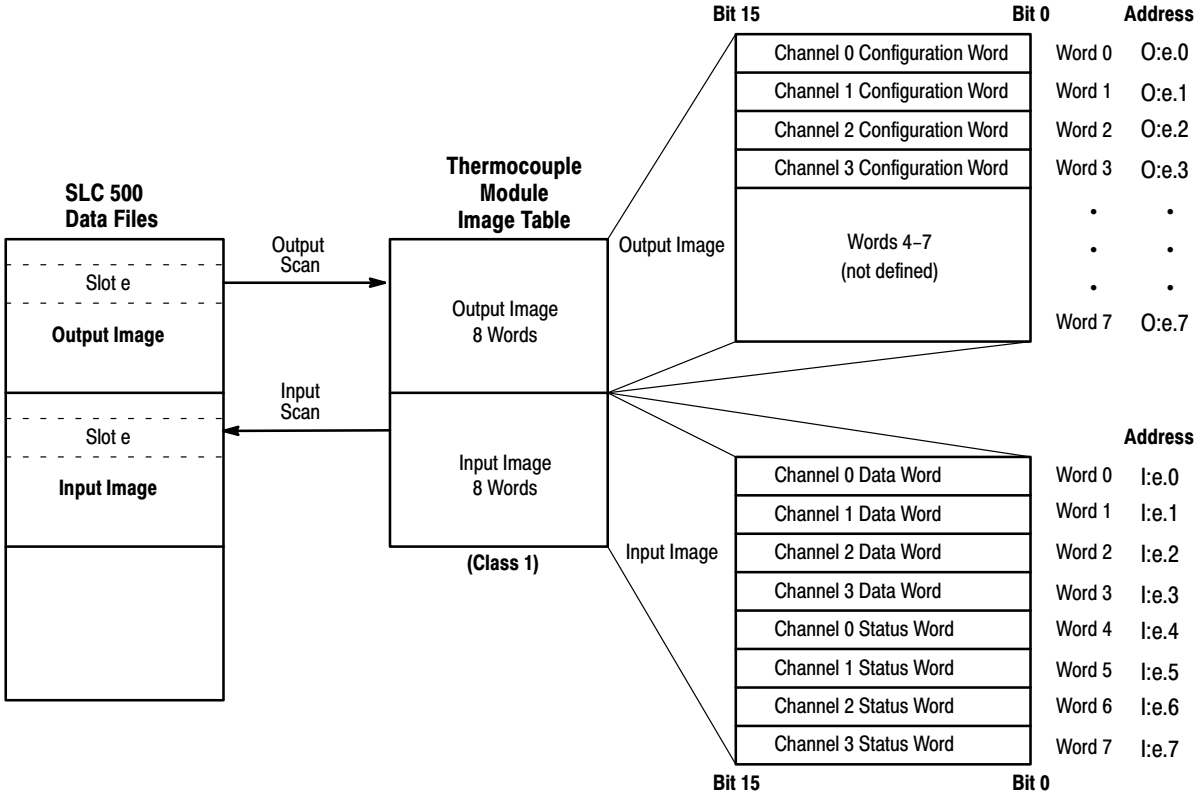
① Refer to the Thermocouple/mV Input Module User Manual (publication 1746–6.6.1) for the appropriate use of this new Analog Common terminal when using this module with multiple grounded or exposed thermocouples.

Cold Junction Compensation (CJC)

To obtain accurate readings from each of the channels, the cold junction temperature (temperature at the module's terminal junction between the thermocouple wire and the input channel) must be compensated for. Two cold junction compensating thermistors have been integrated in the removable terminal block to accomplish this function and maintain high system accuracy.

Module Addressing

The following memory map shows you how the output and input image tables are defined for the thermocouple module.



Channel Configuration (Output Image)

Once the module has been installed, each channel on the module can be configured to establish the way the channel will operate. You configure the channel by entering bit values into the configuration word using your programming software. Channels 0–3 on the NT4 module are configured by entering bit values into output words 0–3 respectively. Output words 4–7 are not used.

You can configure the following parameters:

Parameter	Select one of these
Thermocouple Type	J, K, T, E, R, S, B, or N
Millivolt Type	±50 mV or ±100 mV
Temperature Units	°C or °F
Data Format	1.0 degrees or 0.1 degrees 0.1 mV or 0.01 mV scaled-for-PID or proportional counts
Filter Frequency	10 Hz, 50 Hz, 60 Hz, or 250 Hz
Open Circuit Failure	Zero, upscale, or downscale

The format of the data that the NT4 sends back to the SLC processor depends on how the bits are set in the configuration word. Specific bit fields represent various channel characteristics. Each of these characteristics can be modified from its power-up default setting at installation or dynamically redefined while the module is operating.

Specific bit settings are discussed in the Thermocouple/mV Input Module User Manual (publication number 1746-6.6.1). The tables on the next page define the data and display formats and the resolutions that can be represented for each input type.

In these tables:

- **Engineering Units** provide the input value directly in °C, °F, or millivolts.
- **Scaled-for-PID** provides a data format directly compatible with the SLC 5/02™ and later processors PID algorithm.
- **Proportional Counts** provide the greatest possible resolution but require manual conversion to engineering units.

1746-NT4 Thermocouple Module – Channel Data Word Format (thermocouples and millivolt sensors)

Input Type	Data Format					
	Engineering Units (in Degrees)		Engineering Units (in tenths of a Degree)		Scaled-for-PID	Proportional Counts
	° Celsius	° Fahrenheit	° Celsius	° Fahrenheit		
J	–210 to 760	–346 to 1400	–2100 to 7600	–3460 to 14000	0 to 16383	–32768 to 32767
K	–270 to 1370	–454 to 2498	–2700 to 13700	–4540 to 24980	0 to 16383	–32768 to 32767
T	–270 to 400	–454 to 752	–2700 to 4000	–4540 to 7520	0 to 16383	–32768 to 32767
E	–270 to 1000	–454 to 1832	–2700 to 10000	–4540 to 18320	0 to 16383	–32768 to 32767
R	0 to 1768	32 to 3214	0 to 17680	320 to 32140	0 to 16383	–32768 to 32767
S	0 to 1768	32 to 3214	0 to 17680	320 to 32140	0 to 16383	–32768 to 32767
B	300 to 1820	572 to 3308	3000 to 18200	5720 to 32767①	0 to 16383	–32768 to 32767
N	0 to 1300	32 to 2372	0 to 13000	320 to 23720	0 to 16383	–32768 to 32767
±50 mV②	–500 to 500		–5000 to 5000		0 to 16383	–32768 to 32767
±100 mV②	–1000 to 1000		–10000 to 10000		0 to 16383	–32768 to 32767
CJC Sensor	0 to 85	32 to 185	0 to 850	32 to 1850	0 to 16383	–32768 to 32767

① Type B thermocouple cannot be represented in tenths of a degree Fahrenheit engineering units above 3276.7°F. Software treats it as over-range error.

② When millivolts are selected, the temperature setting is ignored. Analog input data is the same for either °C or °F selection.

1746-NT4 Thermocouple Module – Channel Data Word Resolution (thermocouples and millivolt sensors)

Input Type	Data Format							
	Engineering Units (in Degrees)		Engineering Units (in tenths of a Degree)		Scaled-for-PID		Proportional Counts	
	° Celsius	° Fahrenheit	° Celsius	° Fahrenheit	° Celsius	° Fahrenheit	° Celsius	° Fahrenheit
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	0.0250°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 mV①	0.1 mV/step		0.01 mV/step		6.104 μV/step		1.526 μV/step	
±100 mV①	0.1 mV/step		0.01 mV/step		12.21 μV/step		3.052 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.

Channel Data and Status (Input Image)

Input words 0–3 (data words) hold the input data that represent the temperature value of thermocouple analog inputs for channels 0–3 respectively. This data word is valid only when the channel is enabled and there are no channel errors.

Input words 4–7 (status words) contain the status of channels 0–3 respectively. The status bits for a particular channel reflect the configuration settings that you have entered into the output image configuration word for that channel, as well as providing information about the channel's operational state. To receive valid status information the channel must be enabled, and the channel must have processed any configuration changes that may have been made to the configuration word.

Module Diagnostics

The thermocouple module performs operations at two levels:

- module level operation
- channel level operation

Module level operation includes functions such as power-up configuration and communication with the SLC processor.

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

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

Power-Up Diagnostics

At module power-up, a series of internal diagnostic tests is performed automatically. If any test fails, a module error results and the status LED remains off.

Channel Diagnostics

When a channel is enabled, a diagnostic check is performed to verify that the channel has been properly configured. In addition, the channel is tested for out-of-range and open-circuit faults on every scan. If the channel is configured for thermocouple input or CJC input, the CJC sensors are also checked for open circuits.

A failure of any channel diagnostic test causes the faulted channel LED to blink. All channel faults are indicated in bits 12–15 of the channel's status word. Channel faults are self-clearing, and the channel LED will stop blinking and resume steady illumination when the fault conditions are removed.

Terms and Abbreviations

Listed below and on the following page are definitions of some of the terms and abbreviations used in the specification tables.

A/D – Refers to the analog to digital converter inherent to the NT4 thermocouple input module. The converter produces a digital value whose magnitude is proportional to the instantaneous magnitude of an analog input signal.

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

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} (V1/V2)

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

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).

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

digital filter – A low-pass noise filter incorporated into the A/D converter. The digital filter provides a very steep roll-off above its cut-off frequency, which provides high frequency noise rejection.

filter frequency – The user-selectable first-notch frequency for the A/D converter's digital filter. The digital filter provides high noise rejection at this frequency.

LSB – (Least Significant Bit) Refers to a data increment defined as the full scale range divided by the resolution. The bit that represents the smallest value within a string of bits.

normal mode rejection – (differential mode rejection) A logarithmic measure in dB, of a device's ability to reject noise signals between or among circuit signal conductors, but not between equipment grounding conductor or signal reference structure and the signal conductors.

resolution – The smallest detectable change in a measurement, typically expressed in engineering units (e.g., 0.1°C) or as a number of bits. For example a 12-bit system has 4,096 possible output states. It can therefore measure 1 part in 4096.

step response – The time required for the analog input signal to reach 100% of its expected final value.

Specifications

Electrical Specifications

Backplane Current Consumption	60 mA at 5V dc 40 mA at 24V dc
Backplane Power Consumption	0.8W maximum (0.3W @ 5V dc, 0.5W @ 24V dc)
Number of Channels	4 (backplane isolated)
I/O Chassis Location	Any I/O module slot except slot 0
A/D Conversion Method	Sigma-Delta Modulation
Input Filtering	Low pass digital filter with programmable notch (filter) frequencies
Normal Mode Rejection (between [+] input and [–] input)	Greater than 100 dB at 50 Hz (10 Hz, 50 Hz filter frequencies) Greater than 100 dB at 60 Hz (10 Hz, 60 Hz filter frequencies)
Common Mode Rejection (between inputs and chassis ground)	Greater than 150 dB at 50 Hz (10 Hz, 50 Hz filter frequencies) Greater than 150 dB at 60 Hz (10 Hz, 60 Hz filter frequencies)
Input Filter Cut-Off Frequencies	2.62 Hz at 10 Hz filter frequency 13.1 Hz at 50 Hz filter frequency 15.72 Hz at 60 Hz filter frequency 65.5 Hz at 250 Hz filter frequency
Calibration	Module autocalibrates at power-up and whenever a channel is enabled.
Isolation	500V dc continuous between inputs and chassis ground, and between inputs and backplane.
Maximum Channel-to-Channel Common-Mode Separation	Series B modules: 2V maximum between any two channels Series A modules: 0V separation

Environmental Specifications

Operating Temperature	0°C to 60°C (32°F to 140°F)	
Storage Temperature	–40°C to +85°C (–40°F to +185°F)	
Relative Humidity	5% to 95% (without condensation)	
Certification (when product or packaging is marked)	**Series A or higher:** • UL listed • CSA approved	**Series B or higher:** • UL listed • CSA approved • CE compliant for all applicable directives
Hazardous Environment Classification	Class I Division 2 Hazardous Environment	

Physical Specifications

LED Indicators	5, green status indicators, one for each of 4 channels and one for module status
Module ID Code	3510
Recommended Cable: for thermocouple inputs . . . for mV inputs . . .	 Appropriate shielded twisted pair thermocouple extension wire① Belden #8761 or equivalent
Maximum Wire Size	Two 14 AWG wires per terminal
Maximum Cable Impedance	25Ω maximum loop impedance, for <1LSB error
Terminal Strip	Removable, Allen-Bradley spare part Catalog Number 1746-RT32

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

Input Specifications

Type of Input (Selectable)	Thermocouple Type J –210°C to 760°C (–346°F to 1400°F) Thermocouple Type K –270°C to 1370°C (–454°F to 2498°F) Thermocouple Type T –270°C to 400°C (–454°F to 752°F) Thermocouple Type E –270°C to 1000°C (–454°F to 1832°F) Thermocouple Type R 0°C to 1768°C (32°F to 3214°F) Thermocouple Type S 0°C to 1768°C (32°F to 3214°F) Thermocouple Type B 300°C to 1820°C (572°F to 3308°F) Thermocouple Type N 0°C to 1300°C (32°F to 2372°F) Millivolt (–50 mV dc to +50 mV dc) Millivolt (–100 mV dc to +100 mV dc)
Thermocouple Linearization	IPTS–68 standard, NBS MN–125, NBS MN–161
Cold Junction Compensation	Accuracy ±1.5°C, 0°C to 85°C (32°F to 185°F)
Input Impedance	Greater than 10 MΩ
Temperature Scale (Selectable)	°C or °F and 0.1°C or 0.1°F
DC Millivolt Scale (Selectable)	0.1 mV or 0.01 mV
Open Circuit Detection Leakage Current	12 nA maximum
Open Circuit Detection Method	Upscale
Time to Detect Open Circuit	500 msec or 1 module update time, whichever is greater
Input Step Response	See channel step response information on page 14.
Display Resolution	See Channel Data Word Resolution table on page 9.
Overall Module Accuracy @ 25°C (77°F)	See Module Accuracy Table, page 15.
Overall Module Drift	See Module Accuracy Table, page 15.
Module Update Time (see p. 14)	The sum of all enabled channel's sample time plus one CJC update time.
Channel Turn-On Time, Reconfiguration Time	Requires up to one module update time plus one of the following: • 250 Hz Filter = 82 milliseconds • 60 Hz Filter = 196 milliseconds • 50 Hz Filter = 226 milliseconds • 10 Hz Filter = 946 milliseconds
Channel Turn-Off Time (see p. 14)	Requires up to one module update time

Channel Step Response

The channel filter frequency determines the channel's step response. The step response is time required for the analog input signal to reach 100% of its expected final value. This means that if an input signal changes faster than the channel step response, a portion of that signal will be attenuated by the channel filter.

The following table shows the available filter frequencies, associated minimum normal mode rejection (NMR), cut-off frequency, and step response for each filter frequency.

Filter Frequency	50Hz NMR	60Hz NMR	Cut-Off Frequency	Step Response
10 Hz	100 dB	100 dB	2.62 Hz	300 msec
50 Hz	100 dB	–	13.1 Hz	60 msec
60 Hz	–	100 dB	15.72 Hz	50 msec
250 Hz	–	–	65.5 Hz	12 msec

Update Time

The thermocouple module update time is defined as the time required for the module to sample and convert the input signals of all enabled input channels and make the resulting data values available to the SLC processor. It can be calculated by adding the the sum of all enabled channel sample times, plus a CJC update time.

The following table shows the channel sampling times for each filter frequency. It also gives the CJC update time.

Channel Sampling Time for Each Filter Frequency (all values ±1 msec)

CJC Update Time	Channel Sampling Time			
	250 Hz Filter	60 Hz Filter	50 Hz Filter	10 Hz Filter
14 msec	12 msec	50 msec	60 msec	300 msec

The *fastest module update time* occurs when only one channel with a 250 Hz filter frequency is enabled.

Module update time = 12 msec + 14 msec = 26 msec

The *update time* when four channels are configured, each using a 60 Hz filter frequency, is:

Module update time = (4 x 50 msec) + 14 msec = 214 msec

1746-NT4 Module Accuracy

Input Type	With Autocalibration①		Without Autocalibration①
	Maximum Error @ 25°C	Maximum Error @ 77°F	Temperature Drift (0°C–60°C)
J	±1.06°C	±1.91°F	±0.0193°C/°C, °F/°F
K	±1.72°C	±3.10°F	±0.0328°C/°C, °F/°F
T	±1.43°C	±2.57°F	±0.0202°C/°C, °F/°F
E	±0.72°C	±1.3°F	±0.0190°C/°C, °F/°F
S	±3.61°C	±6.5°F	±0.0530°C/°C, °F/°F
R	±3.59°C	±6.46°F	±0.0530°C/°C, °F/°F
B	±3.12°C	±5.62°F	±0.0457°C/°C, °F/°F
N	±1.39°C	±2.5°F	±0.0260°C/°C, °F/°F
±50 mV	±50 μV	±50 μV	±1.0 μV/°C, ±1.8 μV/°F
±100 mV	±50 μV	±50 μV	±1.5 μV/°C, ±2.7 μV/°F

① Assumes the module terminal block temperature is stable.

Allen-Bradley Support

In today's competitive environment, when you buy any product, you expect that product to meet your needs. You also expect the manufacturer of that product to back it up with the kind of customer service and product support that will prove you made a wise purchase.

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- product technical training
- warranty support
- support service agreements

Rockwell *Automation*

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