Analog I/O Modules for SLC™ Processors

Catalog Numbers
1746-NI4, NIO4I, NIO4V, NO4I, NO4V
1746-FIO4I and FIO4V

The 1746- analog I/O modules offer you a wide range of solutions to your analog control applications.

The 1746-NI4, NIO4V, NIO4I, NO4I, and NO4V modules have a higher-resolution input and are best suited for process control applications involving parameters such as flow and temperature. Their superior input filtering offers a high degree of immunity to electrical noise interference.

The 1746-FIO4I and FIO4V modules are ideal for higher-speed applications with more rapidly changing analog signals. Their input filtering is designed for a higher bandwidth. Typical applications include the control of pressure and position in equipment such as hydraulic presses and molding machines.

The output response of both types of modules is identical.

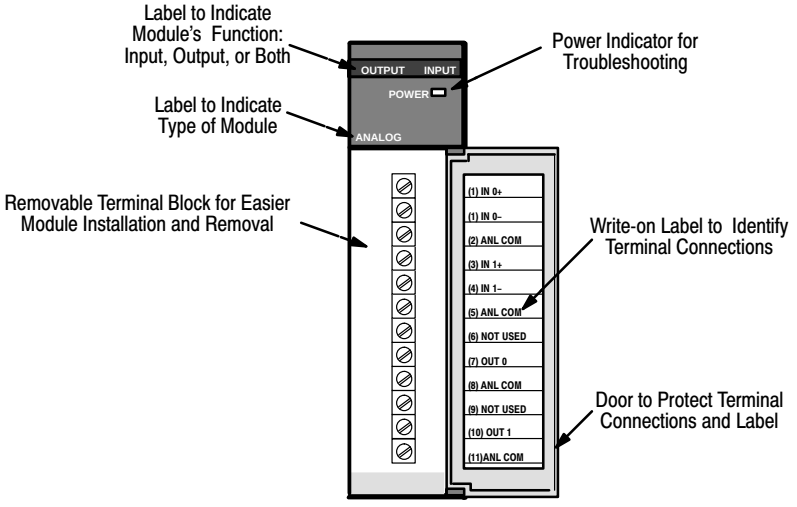
Use this data sheet to select the Allen-Bradley 1746- analog modules best suited for your application.

Features and Benefits

The 1746- analog I/O modules provide these benefits:

Features	Benefits
Single-slot module	Compact I/O structure for your control system.
User-selectable inputs	Lets you configure each input channel for a voltage or current signal from the sensor.
High-resolution (14-bit) outputs	Provides for precision control of analog outputs.
Input filtering	Provides higher immunity to electrical noise (Nxxx) or a faster input response (Fxxx modules).
Automatic end-of-scan I/O updates	No need to program special commands to access analog data, reducing programming time.
Backplane isolation	Isolates input signals from the backplane.
Removable terminal blocks	Lets you replace a module quickly without removing the wiring.
Choice of backplane power or external power supply	Provides flexibility to minimize the cost of power supplies.
UL 508 listed CSA 22.2 142 approved CE compliant for all applicable directives when product or packaging is marked	Lets you install modules in those environments.

The modules have these features:



Front View (Generic)

Overview of Analog Modules

We coded the catalog number of analog modules as follows:

F = faster-response analog modules
N = original higher-resolution analog modules
I (prefix) = input
O (prefix) = output
n = total number of input and/or output channels
I (last) = current output
V (last) = voltage output

For example, the 1746-FIO4I module is a faster input / output module with two inputs (voltage- and/or current-selectable) and two current outputs.

We present the following table of module characteristics to help you select the analog I/O modules best suited to your application:

Characteristic	FIO4I	FIO4V	NI4	NIO4I	NIO4V	NO4I	NO4V
Number of inputs	2	2	4	2	2	n/a	n/a
Input ranges (Select a current or voltage signal for each channel.)	0-10V –1 LSB includes 0-5V dc 1-5V dc 0-21 mA includes 0-20 mA 4-20 mA	0-10V –1 LSB includes 0-5V dc 1-5V dc 0-21 mA includes 0-20 mA 4-20 mA	± 10V dc –1 LSB includes 0-10V dc 0-5V dc 1-5V dc –20 to +20 mA includes 0-20 mA 4-20 mA	± 10V dc –1 LSB includes 0-10V dc 0-5V dc 1-5V dc –20 to +20 mA 0-20 mA 4-20 mA	± 10V dc –1 LSB includes 0-10V dc 0-5V dc 1-5V dc –20 to +20 mA includes 0-20 mA 4-20 mA	n/a	n/a
Input step response	100 µs	100 µs	60 ms	60 ms	60 ms	n/a	n/a
Input filter at 3 db	7k Hz	7k Hz	10 Hz	10 Hz	10 Hz	n/a	n/a
Input A/D converter	12-bit	12-bit	16-bit	16-bit	16-bit	n/a	n/a
Input resolution (I)	9.76 µA per bit	9.76 µA per bit	1.22 µA / LSB	1.22 µA / LSB	1.22 µA / LSB	n/a	n/a
Input resolution (V)	2.44 mV / LSB	2.44 mV / LSB	305.2 µV / LSB	305.2 µV / LSB	305.2 µV / LSB	n/a	n/a
Input coding (I)	0-2047 counts	0-2047 counts	± 16,384 counts	± 16,384 counts	± 16,384 counts	n/a	n/a
Input coding (V)	0-4095 counts	0-4095 counts	± 32,768 counts	± 32,768 counts	± 32,768 counts	n/a	n/a
Input non-linearity	± 0.073% FS	± 0.073% FS	± 0.01% FS	± 0.01% FS	± 0.01% FS	n/a	n/a
Com-mode rejection	50 db @ 60 Hz	50 db @ 60 Hz	105 db @ 60 Hz	105 db @ 60 Hz	105 db @ 60 Hz	n/a	n/a
Number of outputs	2	2	0	2	2	4	4
Output range	0-21 mA –1 LSB includes 0-20 mA 4-20 mA	± 10V –1 LSB includes 0-10V dc 0-5V dc 1-5V dc	n/a	0-21 mA –1 LSB includes 0-20 mA 4-20 mA	± 10V –1 LSB includes 0-10V dc 0-5V dc 1-5V dc	0-21 mA –1 LSB includes 0-20 mA 4-20 mA	± 10V –1 LSB includes 0-10V dc 0-5V dc 1-5V dc
Output D/A converter	14-bit	14-bit	n/a	14-bit	14-bit	14-bit	14-bit
Output coding 0-21 mA	0-32,764	n/a	n/a	0-32,764	n/a	0-32,764	n/a
Output coding ± 10V	n/a	± 32,764	n/a	n/a	± 32,764	n/a	± 32,764

Choosing Between FIO and NIO Analog Modules

The decision to use FIO4I, FIO4V or NI4, NIO4I, NIO4V analog modules is based primarily on the required system response to the input you are measuring or monitoring. The time required for the module and processor to change the output due to a detected change of input must be compatible.

For this I/O system response:	Select from:
63 ms or slower	NI4, NIO4I, NIO4V
4 ms or slower	FIO4I, FIO4V

For example, if you want to control the linear movement of a clamp moving at 20 in/s, the response with a module such as NIO4I could be slower than your positional control tolerance would allow:

0.063 s x 20 in/s = 1.25 inches

A module such as FIO4V would allow a positional control tolerance of:

0.004 s x 20 in/s = .08 inches

Important: For a faster I/O response with an SLC processor, we recommend the you use the following APS programming features:

- Immediate Input Instruction (IIN)
- Immediate Output Instruction (IOT)
- Selectable Timed Interrupt (STI) with a 1 ms period

For more information on how to program the interrupt, refer to your programming software documentation.

Do FIO4I and FIO4V Analog Modules Have Any Unique Considerations?

Yes. FIO4I and FIO4V modules respond faster because the input filter has been modified to allow for higher frequency signals. As a result, the filter may pass more electrical noise. You must take precautions to thoroughly ground and shield the input transducer, its power supply, and cables.

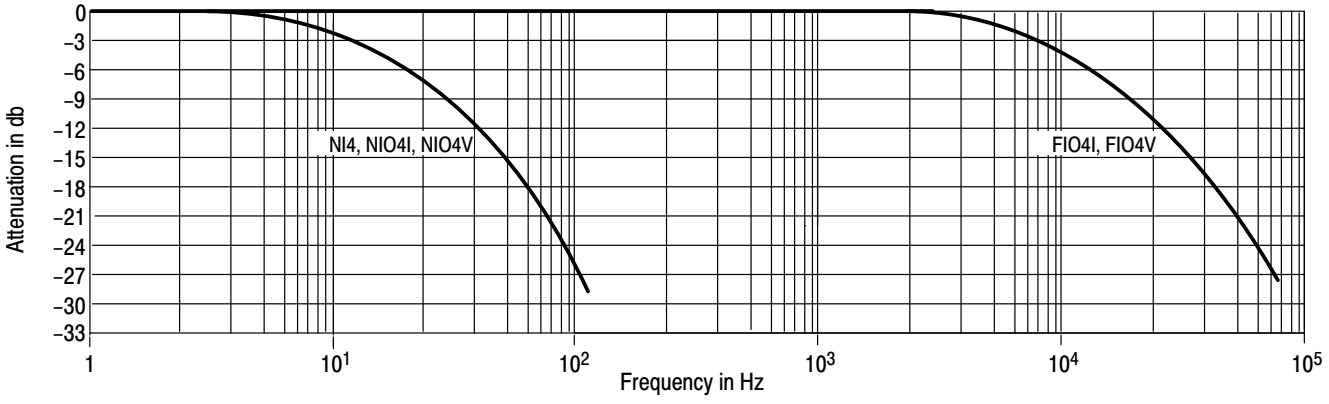
Also, the input resolution of FIO4I and FIO4V modules is considerably less (fewer counts per full scale input) compared to NI4, NIO4I, and NIO4V modules. For example:

Characteristic	FIO4I and FIO4V	NI4, NIO4I, NIO4V
resolution of a 0-20 mA input	0-2047 counts	0-16,384 counts
resolution of a 0-10V dc input	0-4095 counts	0-32,767 counts

A resolution of 0-2047 counts is sufficient for many applications.

Input Filter Characteristics

High frequency noise can couple into the input signal. The purpose of the input filter is to reject noise at frequencies higher than the signal. For NI4, NIO4I, and NIO4V modules, the input bandwidth is 10 Hertz. For FIO4I and FIO4V modules, the bandwidth is about 7000 Hertz and the input filter passes signals up to this frequency to provide the fast response.



Characteristics of the Input A/D Converter

The NI4, NIO4I, and NIO4V modules have different A/D converter characteristics than the FIO4I and FIO4V modules. Differences include:

- input signal ranges
- decimal representation of the analog signal (in the input image table)
- number of significant bits to store the decimal representation
- resolution of the input signal

NI4, NIO4I, and NIO4V Analog Modules

The module converts analog input signals to 16-bit binary values for storage in the SLC processor's input image table.

The decimal range, number of significant bits, and converter resolution depend on the input range that you use for the channel.

NI4, NIO4I, & NIO4V Input Range	Decimal Range (input image table)	Number of Significant Bits	Nominal Resolution
–10 to +10V – 1 LSB	–32,768 to +32,767	16	305.176 μV / LSB
0 to 10V – 1 LSB	0 to +32,767	15	
0 to 5V	0 to 16,384	14	
1 to 5V	3,277 to 16384	13.67	
–20 to + 20 mA	–16,384 to +16,384	15	1.22070 μA / LSB
0 to 20 mA	0 to 16,384	14	
4 to 20 mA	3,277 to 16,384	13.67	

FIO4I and FIO4V Analog Modules

The module converts analog input signals to 12-bit binary values for storage in the SLC processor's input image table.

The decimal range, number of significant bits, and converter resolution depend on the input range that you use for the channel.

FIO4I & FIO4V Input Range	Decimal Range (input image table)	Number of Significant Bits	Nominal Resolution
0 to 10V – 1 LSB	0 to 4095	12	2.4414 mV / LSB
0 to 5V	0 to 2047	11	
1 to 5V	409 to 2047	10.67	
0 to 20 mA	0 to 2047	11	9.7656 μA / LSB
4 to 20 mA	409 to 2047	10.67	

Characteristics of the Output D/A Converter

The analog modules have the same output characteristics.

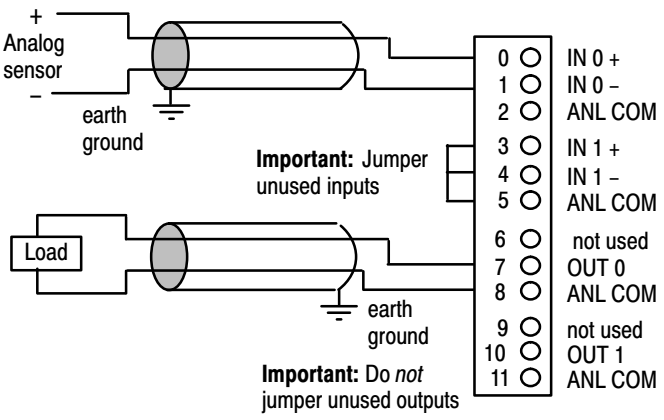
Module	Output Range	Decimal Range (output image table)	Significant Bits	Resolution
FIO4I, NIO4I, NO4I	0-21 mA – 1 LSB	0-32,764	13 bits	2.56348 μA / LSB
	0-20 mA	0-31,208	12.92 bits	
	4-20 mA	6,242-31,208	12.6 bits	
FIO4V, NIO4V, NO4V	–10 to +10V dc – 1 LSB	–32,768 to +32,764	14 bits	1.22070 mV / LSB
	0-10V dc – 1 LSB	0-32,764	13 bits	
	0-5V dc	0-16,384	12 bits	
	1-5V dc	3,277-16,384	11.67 bits	

Wiring Your Module

Your module is designed for differential inputs and outputs. Wire them as follows:

Wiring Differential Analog Inputs and Outputs

Important: Channels are *not* isolated from each other.
All analog commons (ANL COM) are connected together internally.

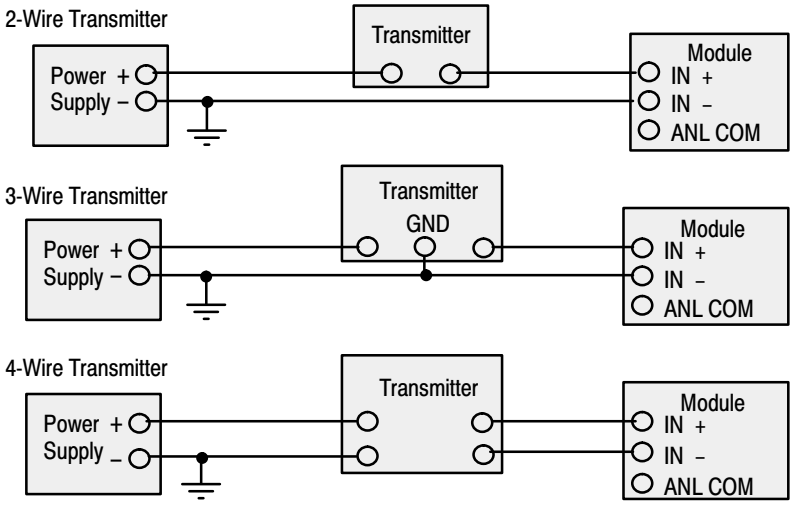


As an alternative, you may wire input transmitters having 2-wire, 3-wire, or 4-wire inputs in a single-ended current-loop configuration.

Important: If using single-ended inputs, we recommend that you take extra precautions for proper grounding and shielding because of the greater noise susceptibility of single-ended inputs.

Wiring Single-ended Current-loop Analog Inputs

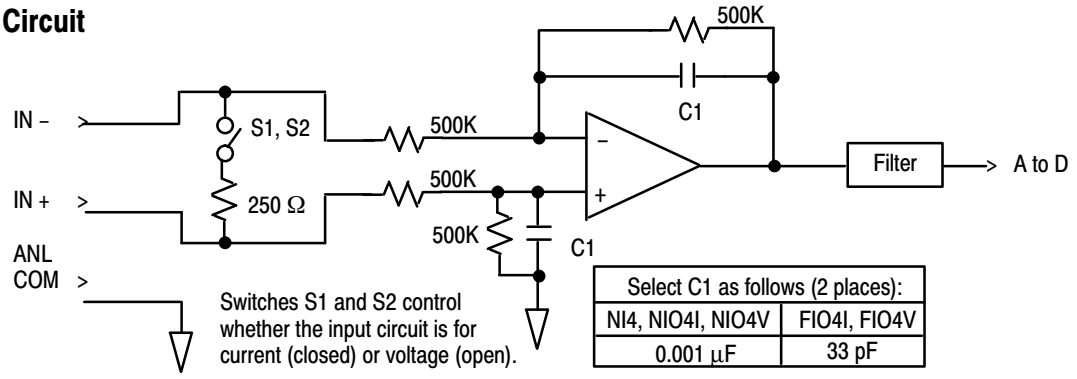
Important: The module does *not* provide loop power for analog inputs.
Use a power supply that matches the transmitter specifications.



Internal Input and Output Circuits

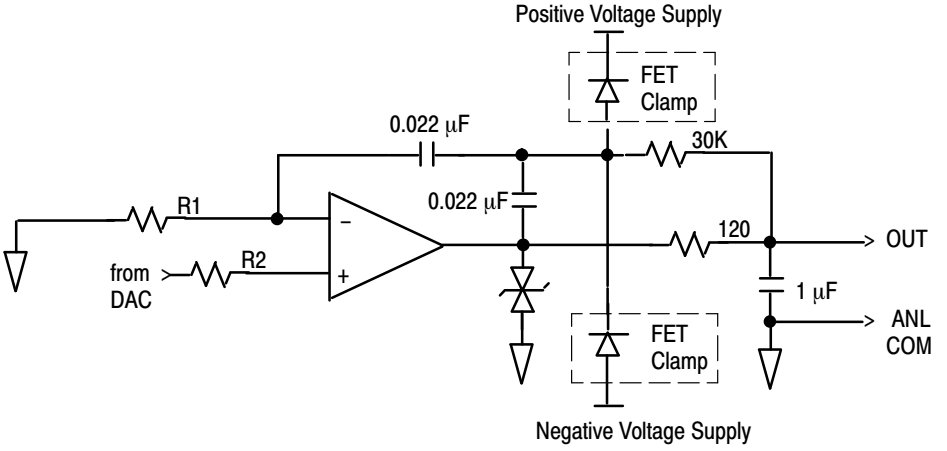
To help you match analog modules to your input and output devices, we provide module input and output circuits as follows:

Input Circuit

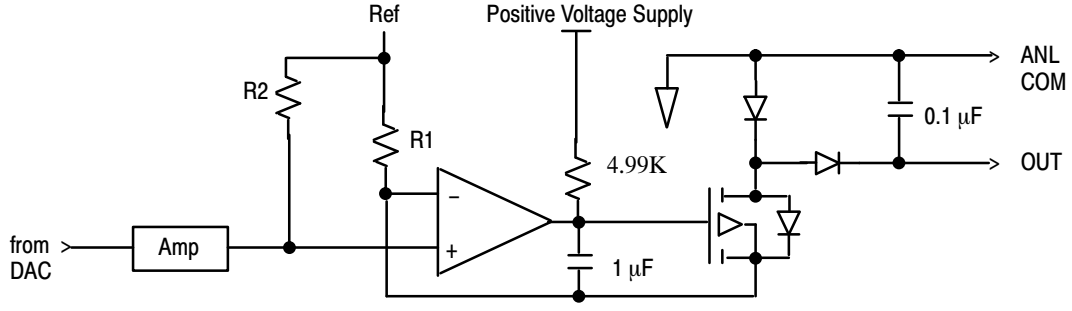


Select C1 as follows (2 places):	
NI4, NIO4I, NIO4V	FIO4I, FIO4V
0.001 μF	33 pF

Voltage Output Circuit



Current Output Circuit



Terms Used in the Specifications

For your convenience, we have included descriptions of parameters defined in the specifications.

- **Common Mode Rejection Ratio** — The ability of a differential analog input to reject common voltage levels at specified frequencies, expressed in db.
- **Common Mode Voltage** — A voltage that appears in common at both input terminals of a differential analog input with respect to ground.
- **Common Mode Voltage Range** — The largest voltage allowed at either input terminal of a differential analog input with respect to ground.
- **Differential Operation** — The use of floating analog inputs or outputs where neither terminal of the input pair or output pair is grounded.
- **Maximum Differential Voltage** — The largest voltage difference allowed between negative and positive terminals during normal differential operation.
- **Full Scale** — The magnitude of voltage or current over which normal operation is permitted.
- **Gain Error** — The "gain" of an analog input or output is the scale factor which provides the nominal conversion relationship. Typically, this is the slope of the line when analog voltage or current is plotted versus the corresponding digital codes. Gain error is the deviation of the scale factor or slope of the line from the ideal or nominal value. Gain error is expressed in percent of the input or output value.
- **Gain Error Drift** — The effect of temperature on gain error is expressed by gain error drift. As temperature varies from +25°C, the possible gain error increases. The gain error drift is specified in percent of input or output value /°C.
- **Linearity Error** — An analog input or output is composed of a series of voltage or current values corresponding to digital codes. For an ideal analog input or output, the values lie in a straight line spaced by a voltage or current corresponding to 1 LSB. Any deviation of the converted input or actual output from this line is the linearity error of the input or output. The linearity is expressed in percent of full scale.
- **Least Significant Bit (LSB)** — The bit in a binary word that carries the smallest value. For the 1746 series of analog modules, I/O image values are 16-bit two's complement binary codes. For analog inputs, the LSB is defined as the rightmost bit, bit 0, of the 16-bit field. For analog outputs, the two rightmost bits are not used, and the LSB is defined as the third bit from the right, bit 2 of the 16-bit field.
- **Module Access Time** — The time between updates of the analog input value available to the backplane.
- **Number of Significant Bits** — The power of two that represents the total number of completely different digital codes that an analog signal can be converted into or generated from.

- **Offset Error** — For analog inputs, the offset error is the non–zero digital code when zero voltage or zero current is applied to the input terminals. For analog outputs, the offset error is the non–zero digital code required to produce zero voltage or current at the output terminals.
- **Offset Error Drift** — The effect of temperature on offset error is expressed by offset error drift. As temperature varies from +25°C, the possible offset error increases. The offset error drift is specified in LSB /°C of full scale.
- **Overall Accuracy** — The worst case deviation of the output voltage or current from the ideal over the full output range is the overall accuracy. For inputs, the worst case deviation of the digital representation of the input signal from the ideal over the full input range is the overall accuracy. This is expressed in percent of full scale. Gain error, offset error, and linearity error all contribute to input and output channel accuracy.
- **R-2R Ladder** — The resistive ladder network used in a CMOS D/A converter that divides the input current from a voltage reference into currents that represent binary-weighted counts.
- **Repeatability** — The closeness of agreement among repeated measurements of the same variable under the same conditions.
- **Resolution** — The nominal voltage or current increment that equals the smallest change, step or level, detected or represented by the analog channel.
- **Safe State** — The state of the analog outputs entered when the processor is not in Run mode. The user must insure that this is a safe state for the application.
- **Sigma-delta** — The type of architecture used in an A/D converter that combines oversampling, noise shaping, digital filtering, and decimation. The analog input signal is continuously sampled at a rate determined by master clock and selected gain. A charge-balancing A/D converter (sigma-delta modulator) converts the sampled signal into a digital pulse train whose duty cycle contains the digital information.
- **Step Response** — The time required for the analog input or output signal to change from 5-95% or from 95-5% of its expected final value.
- **Successive Approximation** — A method used in an A/D converter to approximate the input voltage. Starting with the MSB, the method is extended n times for an n-bit converter: if the approximation exceeds a reference, the result is a 0 for that bit; if smaller, the result is a 1.
- **Update Time** — For analog inputs, the time between successive conversions of the analog signal to digital values. For analog outputs, the time between the digital code received at the module and the analog output signal appearing at the channel's output terminals.

Specifications for Analog Modules

General Specifications

Catalog 1746-	ID Code	Input Channels per Module ①	Output Channels per Module ①	Backplane Current 5V	24V
NI4	4401	4 differential, select V or I per channel	NA	25 mA	85 mA
NIO4I	3201	2 differential, select V or I per channel	2 current outputs	55 mA	145 mA
NIO4V	3202	2 differential, select V or I per channel	2 voltage outputs	55 mA	115 mA
NO4I	5401	NA	4 current outputs	55 mA	195 mA ②
NO4V	5402	NA	4 voltage outputs	55 mA	145 mA ②
FIO4I	3224	2 differential, select V or I per channel	2 current output	55 mA	150 mA
FIO4V	3218	2 differential, select V or I per channel	2 voltage outputs	55 mA	120 mA

① Input and output channels are isolated from the backplane but not from each other.

② If an external 24V power supply is required, the tolerance must be 24V ± 10% (21.6 to 26.4V dc.) The modular system power supply, 1746-P1 or -P2, does NOT meet this specification.

Description	Specification
SLC Communication Format	16-bit two's compliment binary
Location of LSB in I/O Image Word	0000 0000 0000 0001
Impedance to ANL COM	500K ohms
Impedance, Channel-to-channel	1M ohms
Field Wiring to Backplane Isolation	500V dc (continuous)
Cable	shielded, Belden #8761 (recommended)
Wire Size	#14 AWG (max)
Grounding Wire (optional)	1/4" wide (min) brade
Terminal Block, 1746-RT28	removable
Installation	single slot in the 1746 I/O Rack
Calibration	factory calibrated
Noise Immunity	NEMA standard ICS 2–230
Environmental Conditions Operating Temperature Storage Temperature Relative Humidity	 0-60°C (32-140°F) –40° to 85°C (–40° to 185°F) 5-95% (non–condensing)
Certification	UL 508 listed, CSA 22.2 142 approved CE compliant for all applicable directives when product or packaging is marked

General Input Specifications

Description	General Input Specifications NI4, NIO4I, and NIO4V	General Input Specifications FIO4I and FIO4V
Step Response (5-95%)	60 ms	100 μsec
Converter Resolution	16-bit	12-bit
Conversion Method	sigma-delta modulation	successive approximation
Non–linearity	0.01% of full scale (max)	±0.073% of full scale (max)
Common Mode Voltage Range	–20 to +20V dc	0-20V dc (max)
Common Mode Rejection Ratio at 10 Hz	50 db	n/a
Common Mode Rejection Ratio at 60 Hz	105 db	50 db (min), 1K ohm imbalance
Normal Mode Rejection at 60 Hz (min.)	55 db	n/a
Channel Bandwidth	10 Hz	7.0K Hz (min) @ 3 db point
Image Format (HEX)	0FFF	0FFF
Track/hold Time to Get Signal before Conversion	n/a for sigma-delta modulation	1.5 μs (nominal)
Signal Convert From Hold	n/a for sigma-delta modulation	6.0 μsec (nominal)
Conversion Time	n/a for sigma-delta modulation	7.5 μsec every 512 μsec (nominal)
Module Throughput Delay	512 μsec (nominal)	1.10 ms (max[1]) 512 μsec (typical)

[1] Worst case throughput occurs when the module just misses seeing an event occur.

Current-loop Input Specifications

Description	Current Input Specifications NI4, NIO4I, and NIO4V	Current Input Specifications FIO4I and FIO4V
Full Scale	20 mA	20 mA
Input Range	–20 to +20 mA (nominal) –30 to +30 mA (max)	0-20 mA (nominal) 0-30 mA (max)
Current Input Coding	–16,384 to +16,384 for –20 to +20 mA	0-2047 counts for 0-20 mA
Absolute Maximum Input Voltage	±7.5V dc or 7.5V ac RMS	±7.5V dc or 7.5V ac RMS
Input Impedance	250 ohms	250 ohms (nominal)
Resolution	1.22070 μA per LSB	9.7656 μA per bit
Overall Accuracy at 25°C (77°F)	±0.365% of full scale	±0.510% of full scale
Overall Accuracy, 0-60°C (32-140°F)	±0.642% of full scale (max)	±0.850% of full scale
Overall Accuracy Drift	±79ppm/°C of full scale	±98 ppm/°C of full scale (max)
Gain Error at 25°C (77°F)	±0.323% (max)	±0.400% of full scale
Gain Error, 0-60°C (32-140°F)	±0.556% (max)	±0.707% of full scale
Gain Error Drift	±67ppm/°C	±89 ppm/°C (max)
Offset Error at 25°C (77°F)	±7 LSB (max)	±2 LSB (typical)
Offset Error, 0-60°C (32-140°F)	±14 LSB (max)	±4 LSB
Offset Error Drift	±0.20 LSB/°C	±0.14 LSB/°C (max[1])
Overvoltage Protection	7.5V ac RMS (max)	7.5V ac RMS (max)

[1] Computed by box method: 2 [max offset error] / 60°C

Voltage Input Specifications

Description	Voltage Input Specifications NI4, NIO4I, and NIO4V	Voltage Input Specifications FIO4I and FIO4V
Full Scale	10V dc	10V dc
Input Range	–10 to +10V dc – 1 LSB	0-10V dc –1 LSB
Input Impedance	1M ohms	1M ohms (nominal)
Overvoltage Protection (IN+ to IN–)	220V dc or ac RMS continuously	220V dc or ac RMS, continuously
Resolution	305.176 μV per LSB	2.4414 mV per LSB (nominal)
Voltage Input Coding	–32,768 to +32,767 for –10 to +10V dc	0-4095 counts for 0-10V dc
Overall Accuracy at 25°C (77°F)	±0.284% of full scale (max)	±0.440% of full scale
Overall Accuracy, 0-60°C (32-140°F)	±0.504% of full scale (max)	±0.750% of full scale
Overall Accuracy Drift	±63 ppm/°C of full scale (max)	±88 ppm/°C (max)
Gain Error at 25°C (77°F)	±0.263% (max)	±0.323% of full scale
Gain Error, 0-60°C (32-140°F)	±0.461% (max)	±0.530% of full scale
Gain Error Drift	±57 ppm/°C (max)	±79 ppm/°C (max)
Offset Error, 0-60°C (32-140°F)	±7 LSB (max)	±4 LSB (max)
Offset Error at 25°C (77°F)	±14 LSB (max)	±2 LSB (typical)
Offset Error Drift	±0.20 LSB/°C (max)	±0.14 LSB/°C (max[1])

[1] Computed by box method: 2 [max offset error] / 60°C

Output Specifications

Description	Current Output Specifications FIO4I, NIO4I, and NO4I	Voltage Output Specifications FIO4V, NIO4V, and NO4V
Full Scale	21 mA	10V dc
Output Range	0-20 mA –1 LSB (normal)	–10 to +10V – 1 LSB (normal)
Output Coding	0-32,764 for 0-21 mA	–32,768 to +32,764 for -10 to +10V dc
Output Resolution	2.56348 μA per LSB	1.22070 mV per LSB
Converter Resolution	14-bit	14-bit
Location of LSB in I/O Image Word	0000 0000 0000 01XX	0000 0000 0000 01XX
Non–linearity	0.05% of full scale (max)	0.05% of full scale
Conversion Method	R–2R ladder	R–2R ladder
Step Response	2.5 ms (5-95%)	2.5 ms (normal)
Load Range	0-500 ohms	1K to ∞ ohms
Load Current	n/a	10 mA (max)
Load Reactance	100 μH (max)	1 μF (max)
Over-range Capability	5% (0-21 mA – 1 LSB)	n/a
Overall Accuracy at 25°C (77°F)	±0.298% of full scale	±0.208% of full scale
Overall Accuracy, 0-60°C (32-140°F)	±0.541% of full scale	±0.384% of full scale
Overall Accuracy Drift	±70 ppm/°C of full scale (max)	±54 ppm/°C of full scale (max)
Gain Error at 25°C (77°F)	±0.298% of full scale	±0.208% of full scale
Gain Error, 0-60°C (32-140° F)	±0.516% of full scale	±0.374% of full scale
Gain Error Drift	±62 ppm/°C (max)	±47 ppm/°C (max)
Offset Error at 25°C (77°F)	±10 LSB (typical)	±9 LSB (typical)
Offset Error, 0-60°C (32-140° F)	±12 LSB	±11 LSB
Offset Error Drift	±0.06 LSB/°C (max)	±0.05 LSB/°C (max)

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 your made a wise purchase.

As the people who design, engineer, and manufacture your Industrial Automation Control equipment, Allen-Bradley has a vested interest in your complete satisfaction with our products and services.

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

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