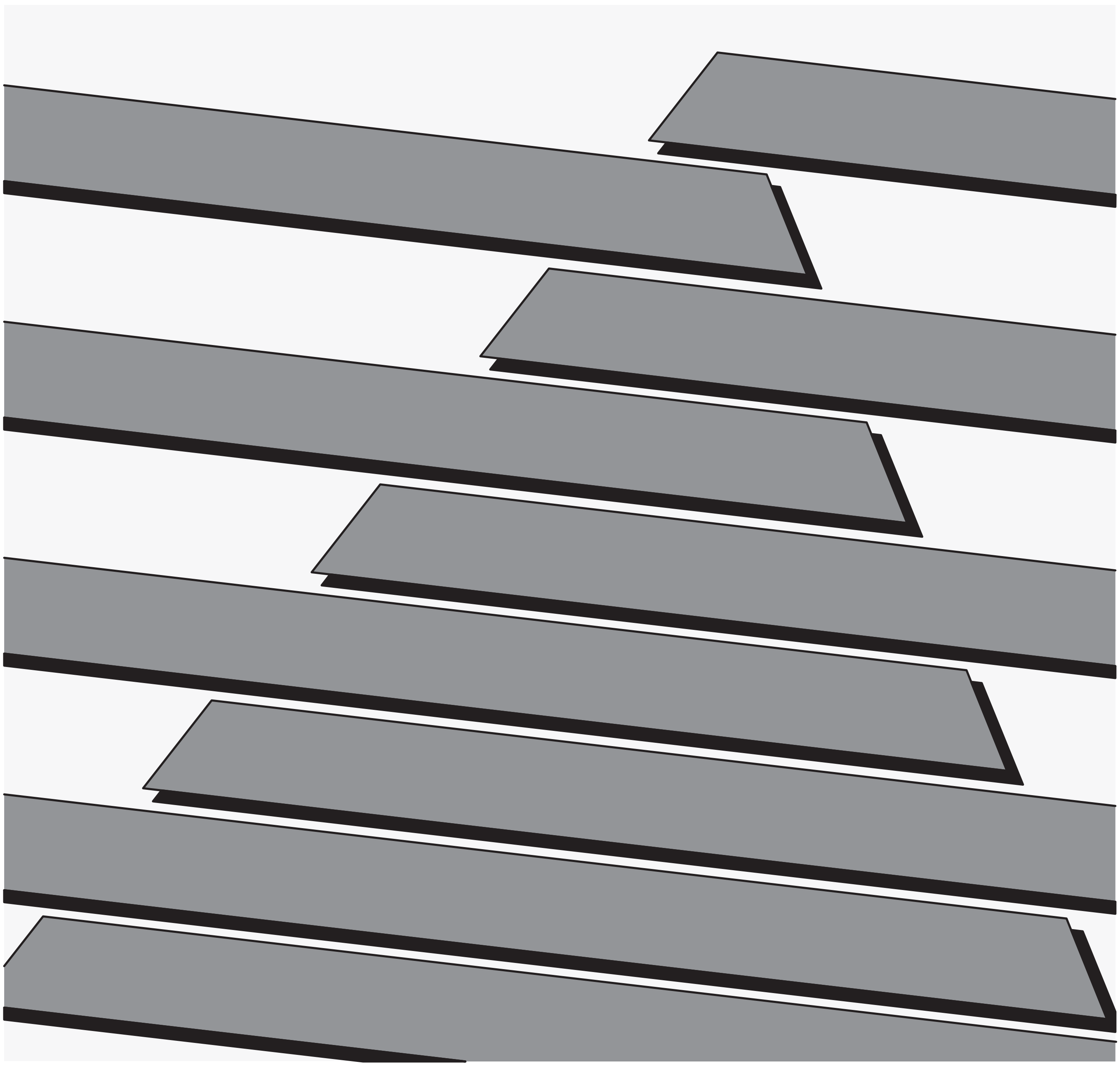
ALLEN-BRADLEY

SLC 500™ Fast Analog I/O Modules

(Catalog Numbers 1746–FIO4I and FIO4V)

User Manual



Important User Information

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

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

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

Throughout this manual we make notes to alert you to possible injury to people or damage to equipment under specific circumstances.

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

Attention helps you:

- Identify a hazard
- Avoid the hazard
- Recognize the consequences

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

Using This Manual

Using This Manual

Read this preface to familiarize yourself with the rest of this manual. It provides information concerning the:

- contents of this manual
- intended audience
- concept of analog control
- common terminology
- definition of terms
- related publications

Contents of this Manual

This manual helps you install the following fast analog I/O modules and integrate them into your SLC 500™ system.

- Catalog Number 1746–FIO4I Fast Analog I/O Module
- Catalog Number 1746–FIO4V Fast Analog I/O Module

The following table identifies the chapters, titles and contents.

Chapter	Title	Describes
1	Quick Start	Abbreviated procedures for the advanced technician, or otherwise used as an overview
2	Installing Modules	How to install and wire the module
3	Processor and Module Considerations	Monitoring I/O data, addressing I/O image words, signal resolution and conversion in I/O channels
4	Create or Open a File and Configure the Software	Procedures to create new files or return to existing files to configure software or write ladder logic
5	Programming Examples	How to program analog modules
6	Calibrating the Module	How to write ladder logic to maintain a calibrated input reference and to calibrate the module
8	Maintenance, Safety, and Troubleshooting	Preventive maintenance suggestions, safety considerations, and troubleshooting
7	Testing Your Module	How to test analog modules during initial installation
A	Module Specifications	Detailed technical specifications
B	2’s-complement Binary Numbers	Explanation of how to use this number system
C	Module I/O Circuits	Internal wiring of the module’s I/O circuits

Intended Audience

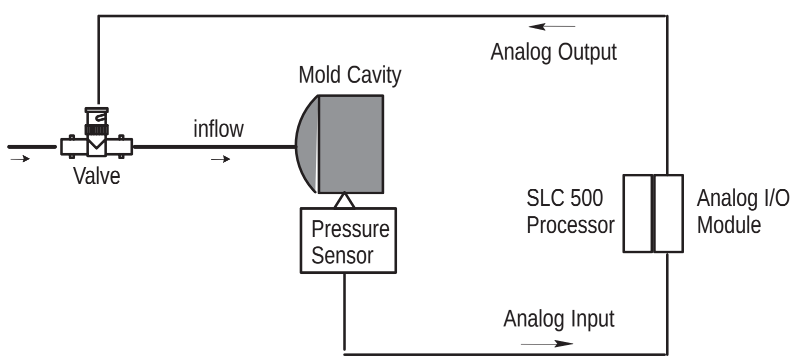
We assume that you have a working knowledge of the SLC 500 family of processors and related products. If you do not, obtain the proper training from your local sales or distributor office.

Concept of Analog Control

Analog control of a process refers to *continuous* control, where the signal amplitude varies with time. With digital control, the signal amplitude jumps between zero and a maximum value (on/off) with time. The following example shows a conceptual analog control application.

In this conceptual example, molding material is forced into the mold cavity at controlled pressure. The purpose of the control system is to control the pressure in the mold cavity according to a pressure algorithm programmed into the processor. The pressure algorithm controls filling the mold cavity rapidly and attaining the desired density of material in the mold cavity.

The analog I/O module converts the analog signal from the pressure sensor (process variable) to a digital signal for transfer to the processor. The module also converts the digital signal from the processor to an analog signal (control variable) to control the pressure in the mold cavity by adjusting pressure or flow through the valve. The pressure algorithm is a ladder program stored in processor memory.



Fast Analog Response

Standard analog I/O modules respond to changes in analog signals measured in seconds. Fast analog I/O modules respond to changes in analog signals measured in milliseconds. What you gain in faster response, you loose in susceptibility to electrical noise. Fast analog modules respond faster because they have little input filtering. Therefore, we recommend that when using fast analog I/O modules, you take precautions to minimize electrical noise interference. We cover how to do this in chapter 2.

Glossary

For a complete glossary, refer to the Allen-Bradley Industrial Automation Glossary, publication AG-7.1.

A/D Conversion

Generation of a digital value whose magnitude is proportional to the instantaneous magnitude of an analog signal.

Common Mode Rejection

The ability of a differential analog input to cancel a common-mode signal, 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 difference (positive or negative) allowed at either input terminal of a differential analog input with respect to ground.

D/A Conversion

Generation of an analog signal whose instantaneous magnitude is proportional to the magnitude of a digital value.

Differential Voltage, Maximum

The largest voltage difference allowed between the negative terminal and positive terminal during normal differential operation.

Full Scale

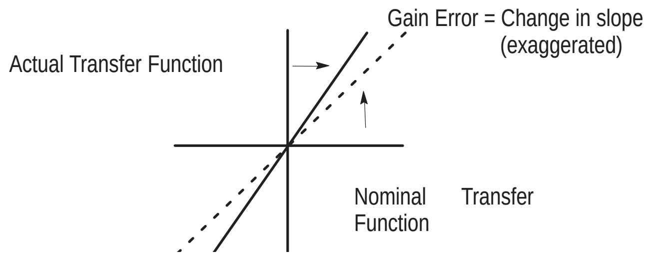
The maximum voltage or current over which normal operation is measured.

Gain

Ratio of output signal to input signal magnitudes. 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. (see Gain Error.)

Gain Error

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 input or output.



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.

I/O Rack

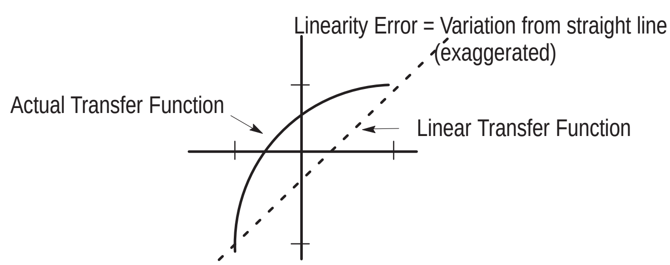
An assembly that typically holds the processor, power supply, and I/O modules that plug into slots. In a modular system, it is a 4-, 7-, 10- or 13–slot I/O rack. In a fixed system, it is a 2–slot expansion I/O rack.

Least Significant Bit (LSB)

The digit (or bit) in a binary word that carries the smallest value or weight. The right-most bit in a 16-bit 2's-complement binary code. For the FIO4I and FIO4V modules, the LSB is defined by I/O channel converters as:
 for outputs, the 3rd rightmost bit, bit 02
 for inputs, the right-most bit, bit 00

Linearity Error

For an ideal A/D or D/A conversion, a graph of the digital values plotted against the corresponding analog values should form a straight line. Linearity error is any deviation from a straight line expressed in percent of full scale.

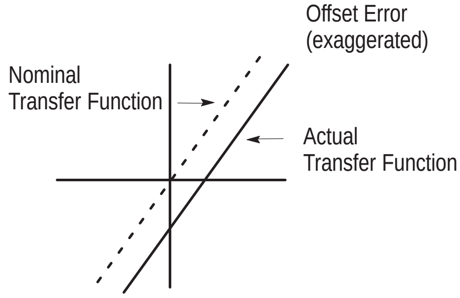


Offset

The steady-state deviation of a controlled variable from a fixed setpoint.

Offset Error

For A/D conversion, the digital value generated by a zero analog signal. For D/A conversion, the digital value that generates a zero analog signal.



Offset Error Drift

The change in offset error due to the change in temperature.
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

For outputs, the worst case deviation of the output voltage or current from the ideal over the full output range. For inputs, the worst case deviation of the digital representation of the input signal from the ideal over the full input range. It is expressed in percent of full scale.

Gain error, offset error, and linearity error all contribute to input and output channel accuracy.

Resolution

The nominal voltage or current increment that equals the smallest change, step or level, detected or represented by the analog channel. For A/D or D/A conversion, may be expressed as the number of bits in the digital value that corresponds to a full-scale analog value.

Safe State

The state to which analog outputs must be set when the processor is not in RUN mode. The user must ensure that this is a safe state for the application.

Step Response Time

The time required for the digital representation of the analog input to reach 95% of the expected final value.

Update Time

For analog inputs, the time between updates to the memory of the analog module of the digital value representing the analog input signal.
For analog outputs, the time from when the digital code is received at the module to when the analog output signal corresponds to that digital value.

Related Publications

You may want to refer to these manuals while working with analog modules:

- SLC 500 System Overview, Publication 1747-2.30
- Getting Started Guide for APS, Publication 1747-6.3
- Industrial Automation Wiring & Grounding Guidelines, Pub 1770-4.1
- Advanced Programming Software User Manual, Publication 1747-6.4
- Advanced Programming Software Reference, Publication 1747-6.11
- Installation and Operation Manual for Fixed or Modular Hardware Programmable Controllers, Publication 1747-6.2 or 1747-NI002
- Safety Guidelines for the Application, Installation, and Maintenance of Solid State Controls, Publication SGI–1.1

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Chapter 1

Quick Start

This chapter presents an overview of installation and start-up procedures to help you get the module working quickly.

It refers to full procedures in corresponding chapters of this manual or in other SLC documentation that may be helpful if you are unfamiliar with programming techniques or system installation.

We recommend that you use this chapter in either of two ways:

- for the experienced user as a fast installation and start-up guide
- for the first-time user as an overview for using the entire manual

Important: If you have any questions about the abbreviated procedures presented in this chapter, *always read the referenced chapters* and other recommended documentation before trying to apply the information.

Required Tools and Equipment

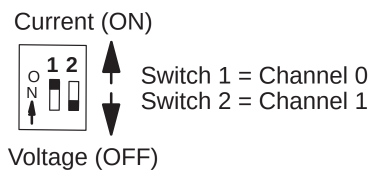
Have the following tools and equipment ready:

- medium flat-head screwdriver
- medium Phillips–head screwdriver
- wire strippers
- utility knife
- hot-air blower
- shrink wrap
- Belden 8761 cable or equivalent
- analog I/O devices for your application
- I/O modules (1746-FIO4I and/or -FIO4V)
- programming equipment

Procedures

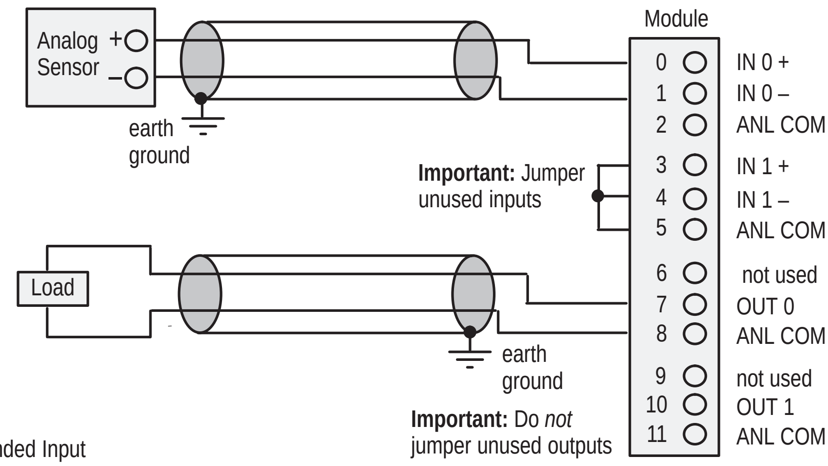
1. Plan the inclusion of analog I/O modules in your SLC system.	Reference
If a new system, specify the type of processor, number of I/O racks, I/O modules, and power supply. If adding to an existing system: • assign modules to slot locations in the I/O rack • verify that the power supply for the I/O rack can handle the increased load	**Worksheet** *at end of chapter* **SLC 500 Overview** **pub 1747-2.30**

2. Configure module input channels for current or voltage operation.	Reference
Locate the 2-switch assembly on the module's circuit board, and set each channel as follows: (The example shows channel 1 set for current and channel 2 set for voltage operation.)	**Chapter 2** *Installing the Module*

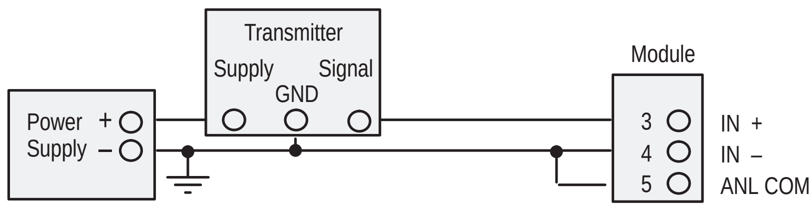


3. Connect I/O devices with cables.	Reference
Important: • Connect only one end of the cable shield to earth ground. • Channels are not isolated from each other. All analog commons are connected together internally. • The module does not provide loop power for analog inputs. • Use a power supply that matches the transmitter (sensor) specifications.	**Chapter 2** *Installing the Module*

For Differential Inputs



For Single-ended Input
with 3-Wire Transmitter



4.	Configure system I/O and module ID.	Reference

With APS, software configure the processor, I/O racks, slots, and I/O modules.

When assigning an I/O module to a slot location, select the module from the displayed list.
If not listed, select `Other` at the bottom of the list and enter the module's ID code at the prompt.

ID code for 1746-FIO4I is 3224
ID code for 1746-FIO4V is 3218

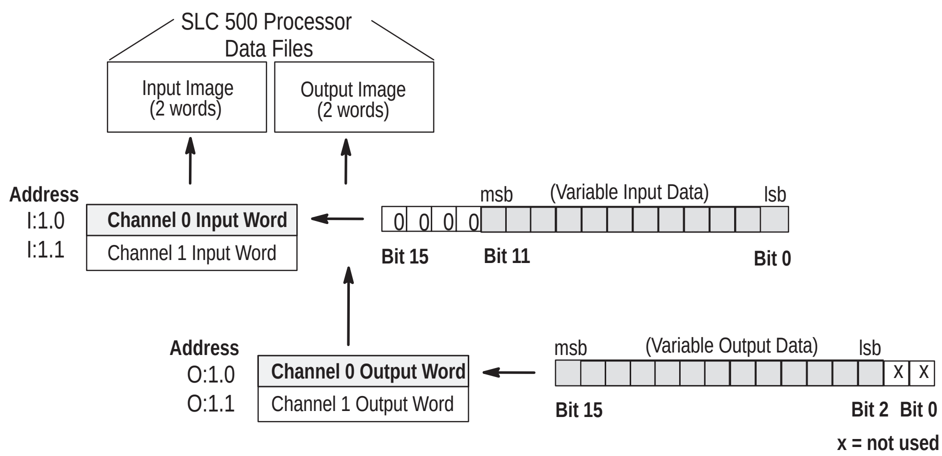
Chapter 3
Accessing Files to Configure I/O

APS User Manual pub. 1747-6.4

5.	Understand A/D & D/A converter resolution on input and output words.	Reference

The module's I/O channel converters limit bit usage to less than a full 16-bit word.
The input channel converter resolution is 12 bits, where the highest four bits are always zero.
The output channel converter resolution is 14 bits, where the lowest two bits are never used.
The lowest two bits have no effect on the output value.

Chapter 4
Processor and Module Considerations



6.	Write ladder logic to process the module's analog data.	Reference

We provide several programming examples that include:

- clear the output when changing mode or cycling power
- detect an out-of-range input
- scale analog outputs
- scale offsets
- scale and range-check analog inputs and outputs
- PID control with analog I/O scaling

Study these examples to understand how to program the module.

Chapter 5
Writing Ladder Logic

APS User Manual pub. 1747-6.4

7.	(Optional) Write ladder logic to maintain calibrated inputs.	Reference

We show you how to write ladder logic that provides a calibrated input reference during runtime, and lets you periodically calibrate module inputs. We suggest that you modify the logic examples to suit your application and add them to your application program.

Chapter 6
Calibrating the Module

SLC System Configuration Worksheet

1. Identify the SLC processor.

Processor Type		**SLC 5/03 Operating System**
SLC 5/01 _______		(from processor label)
SLC 5/02 _______		
SLC 5/03 _______	>>>>	OS300 ____ or OS301 ___
SLC 5/04 _______		

2. Identify I/O rack types and assign I/O modules to slot locations (30 slots max).
Important: FIO4I and FIO4V modules are sensitive to radiated electrical noise and temperature variations. Select I/O slots farthest from ac modules, high-voltage dc modules, power supplies, and other heat sources. If using an enclosure, locate these modules in the coolest area of the enclosure, usually near the bottom.

	2-slot >		4-slot >		7-slot >			10-slot >			13-slot >		
	01	02	03	04	05	06	07	08	09	10	11	12	13
Rack 1 ___-Slot													
Rack 2 ___-Slot													
Rack 3 ___-Slot													

3. Tally I/O points.
Enter totals of digital and analog I/O points.

Inputs		Outputs	
Digit	Anlog	Digit	Anlog

4. Identify power supply requirements.
Enter module power requirements by slot location. Total module power must be less than that of the power supply.

Rack 1				Rack 2				Rack 3			
Slt	Module	I@5v	I@24v	Slt	Module	I@5v	I@24v	Slt	Module	I@5v	I@24v
00	Proc										
01											
02											
03											
04											
05											
06											
07											
08											
09											
10											
11											
12											
13											
Total				Total				Total			
PS Spec				PS Spec				PS Spec			

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Processor	I@5v	I@24v
SLC 5/01	0.35	0.105
SLC 5/02	0.35	0.105
SLC 5/03	0.50	0.175
SLC 5/04	0.65	0.200

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Power Supply	I@5v	I@24v
1746-P1	2.0A	0.46A
1746-P2	5.0A	0.96A
1746-P3	3.6A	0.87A
1746-P4	10.0A	2.8A

Module	I@5v	I@24v	Module	I@5v	I@24v	Module	I@5v	I@24v	Module	I@5v	I@24v	Module	I@5v	I@24v	Module	I@5v	I@24v
FIO4I	0.055	0.150	IG16	0.140	–	ITB16	0.085	–	NO4V	0.055	0.145	OG16	0.180	–	BASIC	0.150	0.040
FIO4V	0.055	0.120	IM4	0.035	–	ITV16	0.085	–	NT4	0.060	0.020	OV8	0.135	–	BASICn	0.150	0.125
IA4	0.035	–	IM8	0.050	–	IV8	0.050	–	OA8	0.185	–	OV16	0.270	–	DCM	0.360	–
IA8	0.050	–	IM16	0.085	–	IV16	0.085	–	OA16	0.370	–	OV32	0.452	–	HS	0.300	–
IA16	0.085	–	IN16	0.085	–	IV32	0.106	–	OB8	0.135	–	OW4	0.045	0.045	KE	0.150	0.040
IB8	0.050	–	IO4	0.030	0.025	NIO4I	0.055	0.145	OB16	0.280	–	OW8	0.085	0.090	KEn	0.150	0.145
IB16	0.085	–	IO8	0.060	0.045	NIO4V	0.055	0.115	OB32	0.452	–	OW16	0.170	0.180			
IB32	0.106	–	IO12	0.090	0.070	NO4I	0.055	0.195	OBP16	0.250	–	OX8	0.085	0.090	NI4	0.025	0.085

Chapter 2

Installing and Wiring Modules

This chapter describes procedures for installing fast analog I/O modules in a SLC 500 system. Procedures include:

- determining the module's power requirements
- determining compatibility with other I/O modules
- configuring input channels
- selecting the I/O rack slot
- installing the module
- considerations when wiring
  - – system wiring guidelines
  - – grounding the cable
  - – determining cable length
- minimizing electrical noise interference
- wiring the module
- minimizing ground loops
- labeling the terminal block

Determining the Module's Power Requirements

Analog modules require power from the 5V dc and 24V dc backplane power supplies of the SLC 500 system. The following table shows the backplane power requirements for fast analog I/O modules.

Catalog Number	Current @ 5V dc	Current @ 24V dc
1746–FIO4I	55 mA	150 mA
1746–FIO4V	55mA	120mA

Use this table to compute the module's portion of total load on the modular system power supply. For more information, refer to:

- Installation & Operation Manual for Modular Hardware Controllers, publication 1747-6.2
- Installation & Operation Manual for Fixed Hardware Controllers, publication 1747-NI001

Determining Compatibility with Other I/O Modules

If using the expansion rack of a fixed controller (1747-L20, -L30, and -L40), use the following chart to determine whether other types of I/O modules are compatible with fast analog modules. Compatibility is solely based on current drawn from the backplane. For more information, refer to SLC 500 System Overview, publication 1747-2.30.

The • symbol indicates an allowable combination of 1746 I/O modules. The ▽ symbol indicates an auxiliary 24Vdc power supply may be needed.

FIO4I	FIO4V	Module
		FIO4I
		FIO4V
•	•	IA4, IA8, IA16
•	•	IB8, IB16
•	•	IB32
•	•	IG16
•	•	IM4, IM8, IM16
•	•	IN16
•	•	IO4
	•	IO8
		IO12
•	•	ITB16, ITV16
•	•	IV8, IV16, IV32
		NIO4I, NIO4V
▽	▽	NO4I, NO4V
		NI4
•	•	NR4
•	•	NT4
•	•	OA8
		OA16
•	•	OB8
		OB16, OB32
	•	OBP16
•	•	OG16
•	•	OV8
	•	OV16
		OV32
	•	OW4
		OW8, OW16
		OX8
	•	BASIC
		BASn
		DCM
		HS
	•	KE
		KEn

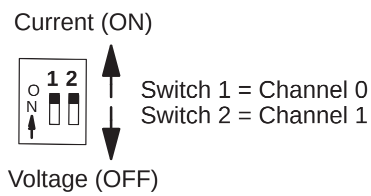
Configuring Input Channels

Your fast analog I/O modules have a 2-switch assembly to configure the input channels for either current or voltage operation. The switches are located on the module's circuit board. Switch orientation is shown on the nameplate of the module as follows:

ON – Configures channel for current input

Off – Configures channel for voltage input

Switches labeled 1 and 2 control the input mode of channels 0 and 1 respectively, as follows:



Selecting the I/O Rack Slot

Two factors determine where you should locate the module in the I/O rack: ambient temperature and electrical noise. Consider the following conditions when selecting an I/O rack slot for the module. Position the module:

- in a slot away from ac or high voltage dc modules
- away from the rack power supply if installed in a modular system
- in the I/O rack lowest in the enclosure for a cooler ambient

Installing the Module

When installing the module in an I/O rack, you do not need 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. To remove the terminal block, grasp it on the top and bottom and pull outward and down.

ATTENTION: Never install, remove, or wire modules with power applied to the I/O rack. Rid yourself of electrostatic charge before handling the module. Electrostatic discharge can degrade module performance or destroy analog circuitry.

Important – Do not tamper with the the module's factory-sealed potentiometer. It does not require any adjustments.

Follow this procedure when installing or removing the module.

1. Verify that input configuration switches 1 and 2 are set correctly.

ATTENTION: Take care to avoid connecting a voltage source to a channel configured for current input. This could result in improper module operation or damage to the module.

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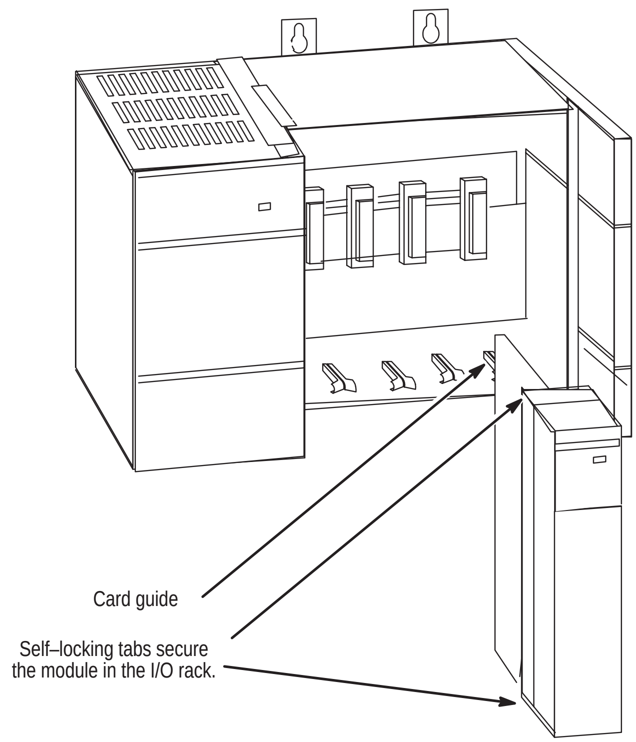
2. Align the module's circuit board with the rack's card guide (Figure 2.1).

3. Slide the module in until top and bottom retaining clips are secured.

4. To remove the module, depress the retaining clips at the top and bottom of the module and slide the module out.

Figure 2.1
Installing the Module



Considerations When Wiring

This section provides guidelines on wiring the system, grounding the cables, determining cable length.

ATTENTION: Before wiring the module, disconnect SLC system power, I/O rack power, and module power.

System Wiring Guidelines

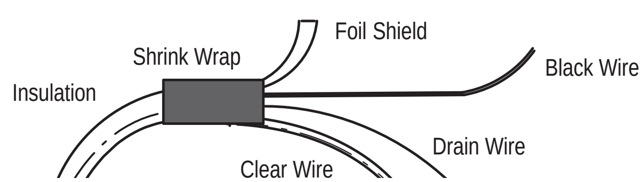
Use the following guidelines in planning the system wiring to the module:

- analog common terminals (ANL COM) are electrically interconnected inside the module, but not *internally* connected to earth.
- voltages on IN+ and IN– terminals must be within 0 to 20 volts with respect to ANL COM to ensure proper input channel operation. This is true for current and voltage input channel operation.
- voltage outputs (OUT 0 and OUT 1) of the FIO4V are referenced to ANL COM. Load resistance (R1) for a voltage output channel must be equal to or greater than 1K ohms.
- current output channels (OUT 0 and OUT 1) of the FIO4I source current that returns to ANL COM. Load resistance (R1) for a current output channel must be within 0 to 500 ohms.
- input connections for single–ended or differential input are the same.

Grounding the Cable

Signal cable such as Belden cable #8761 (or equivalent) has two signal wires (black and clear), one drain wire and a foil shield (Figure 2.2). The drain wire and foil shield must be grounded *at only one end of the cable*, not at both ends.

Figure 2.2
Typical Signal Cable



Important: Ground the cable shield at one end having a good earth-ground connection, such as at an I/O chassis mounting bolt or nearest ground bus in the I/O enclosure. Make this connection as short as possible. *Do not* ground the cable at the module's terminal block.

Determining Cable Length

When you determine the length of cable required to connect an I/O device, remember to include additional length to route the drain wire and foil shield to earth ground. Route your cable long enough to avoid areas of high radiated electrical noise, but short enough to avoid signal attenuation.

Minimizing Electrical Noise Interference

Because high-speed analog signals are particularly vulnerable to electrical noise, take precautions when routing your signal cables. To help reduce the effects of electrical noise on analog signals, we recommend that you:

- Install the SLC 500 system in a NEMA rated enclosure.
- Make sure that the SLC 500 system is properly grounded.
- Use Belden cable #8761 (or equivalent) for signal wiring.
- Ground the cable properly.
- Route signal cables away from other wiring or in grounded conduit.
- Group these modules away from ac or high-voltage dc modules.

We recommend re-checking system operation after installing new machinery or other sources of electrical noise near the system.

For additional information on this subject, refer to Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1.

Wiring the Module

Follow this procedure when wiring your modules.

ATTENTION: Before wiring a module, disconnect power from the SLC 500 system and from any other source to the module.

1. At each end of the cable, strip about 3” of casing to expose the wires.
2. At the ground end of the cable (Figure 2.3), twist the drain wire and foil shield together and bend them away from the cable. With the hot air blower, apply shrink wrap where wires leave the casing.
3. At the other end of the cable, cut off the drain wire and foil shield. Apply shrink wrap to the junction where wires leave the casing.
4. Trim the signal wires to 2-inch lengths. Strip about 3/16 inch (4.76mm) of insulation away to expose the copper strands for your connections.
5. Decide where you will connect the cable to earth ground, and ground it. Refer to Grounding The Cable, above.
6. Connect signal wires (black and clear) to the terminal block and to the input or output device (Figures 2.4 and 2.5).

7. Repeat steps 1 – 6 for each channel. For each unused input channel, jumper together the plus (+), minus (–) and common (ANL COM) terminals. For each unused output channel, do not connect terminals.

Figure 2.3
Cable Preparation

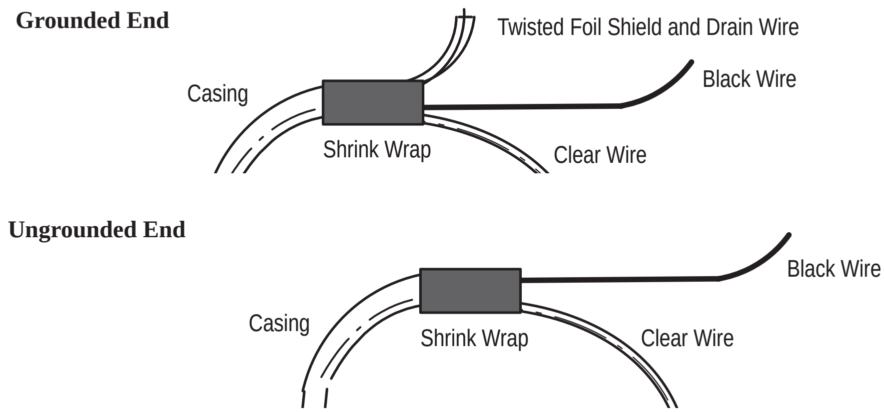


Figure 2.4
Wiring Diagram for Module, Sensor, and Load
(showing differential inputs)

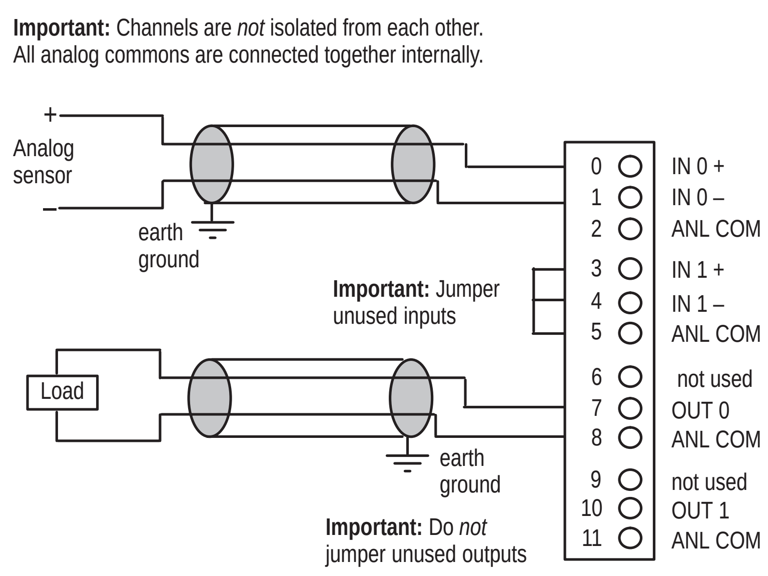
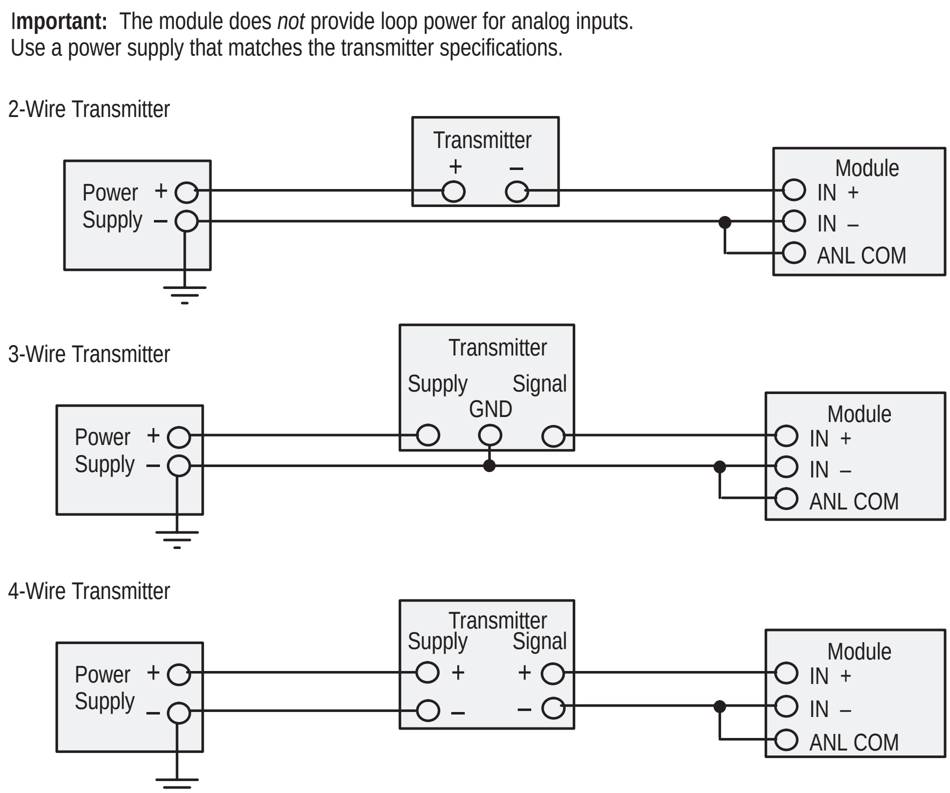


Figure 2.5
Wiring Schematic for Single-ended Current-loop Analog Input Connections
(Single-ended inputs are *less* immune to noise than are differential inputs.)



Minimizing Ground Loops

To keep the ground-loop currents of input circuits (Figure 2.5) to a minimum, we recommend that you:

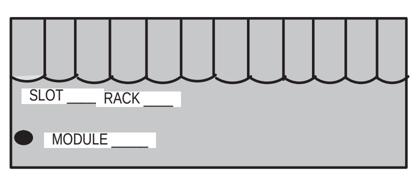
- use the same power supply to power both input channels of a module
- otherwise, tie together the grounds of separate power supplies

Labeling the Terminal Block

The terminal block (Figure 2.6) has a write–on label. Use it to ensure that you install the correct terminal block on the corresponding module.

Figure 2.6
Terminal Block

Note: The black dot on the label indicates the position of terminal 0.



Chapter 3

Accessing Files to Configure I/O

This chapter explains how to apply Advanced Programming Software (APS) to:

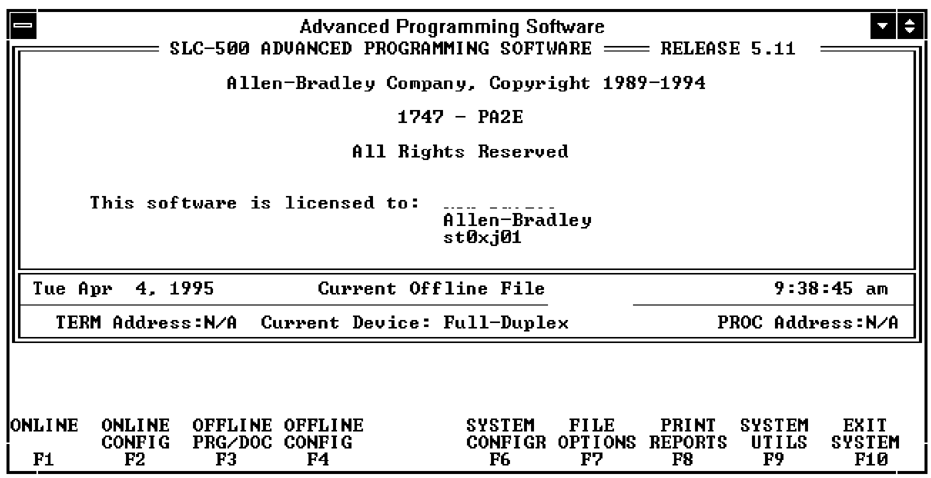
- Create a new file
- Configure I/O
- Return to an existing file

We present abbreviated procedures for limited applications.
For additional information on applying APS, refer to the User Manual for Advanced Programming Software, publication 1747-6.4.

Create a New File

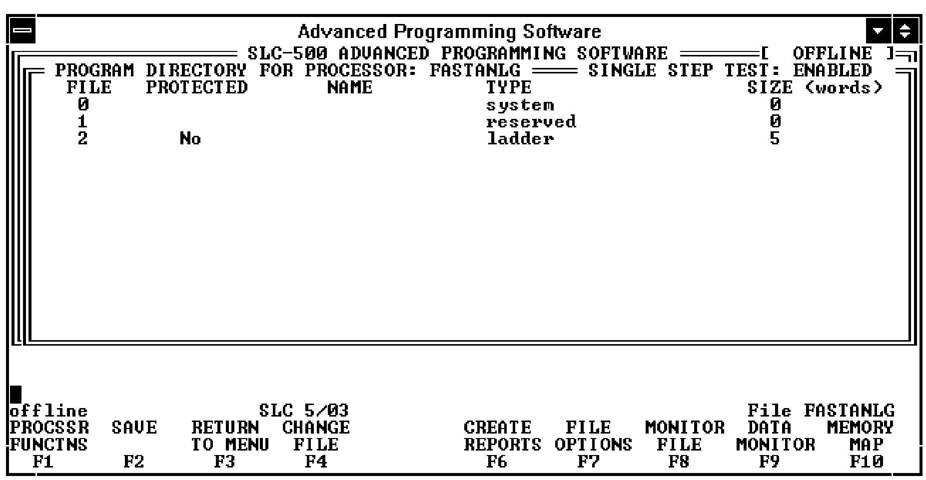
We assume that you have already loaded APS into your computer.

1. Boot your software and access this Main Menu screen.



2. To create a new program file offline, press **`OFFLINE PRG/DOC [F3]`**.

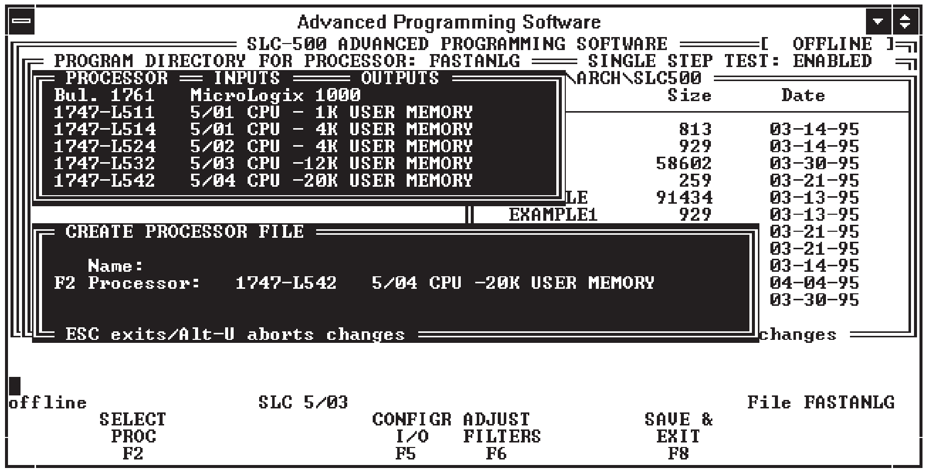
You get the following PROGRAM DIRECTORY FOR PROCESSORS screen.



3. Press these two keys in succession:

`CHANGE FILE [F4]` followed by **`CREATE FILE [F6]`**.

You get the following processor selection screen:



4. Type the name of the file you want to create and press **`[ENTER]`**.

The screen inserts the file name in the lower pop-up window.

5. Identify the type of processor you are using in the upper pop-up window. Use the cursor keys to highlight the processor and press **`[ENTER]`**.

The screen displays processor ID information in the lower pop-up window.

6. What you do next depends on the processor you select.

If you select an:	And:	Then:
SLC 5/03 (or later) processor and press **[ENTER]**	the screen displays another pop-up window	Go to step 7
SLC 5/01 or 5/02 processor	n/a	Go to the section Configure I/O (on next page)

7. Identify the processor's operating system. Read it on the label found on the side of the processor. Then, in the upper pop–up window, cursor to the correct operating system and press **`[ENTER]`**.

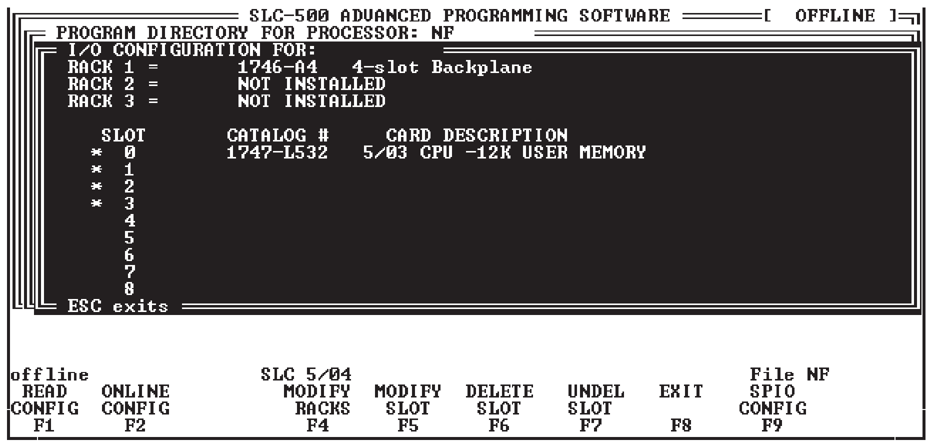
Now you are ready to configure the I/O of your SLC system.
You do this by telling the software what hardware your system is using.

Configure I/O

To configure your I/O, start with the processor selection screen (shown in step 3 on previous page).

1. Press **`CONFIGR I/O [F5]`**.

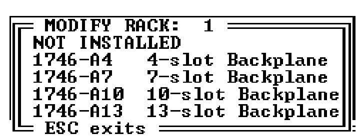
   You get the following I/O configuration screen.



2. What you do next depends on what you want to do.

If you want to:	and your SLC System:	Then press:	and:
use the APS Read Config feature for SLC 5/03 (and later) processors	is installed and wired	**`READ CONFIG [F1]`**	**1.** Follow prompts to configure for SLC system hardware. **2.** Then return to step 10.
manually configure the software	• is a fixed hardware system • uses an SLC 5/01 or 5/02, or • is NOT installed or wired	**`MODIFY RACKS [F4]`**	Go to step 3 next.

3. To configure the first I/O rack, press **`RACK 1 [F1]`**.
   Observe this pop-up window:



4. Cursor to the description of the I/O rack you are using and press **`[ENTER]`**.

   The screen displays the rack description for rack 1 (top of screen), and removes the pop-up window.

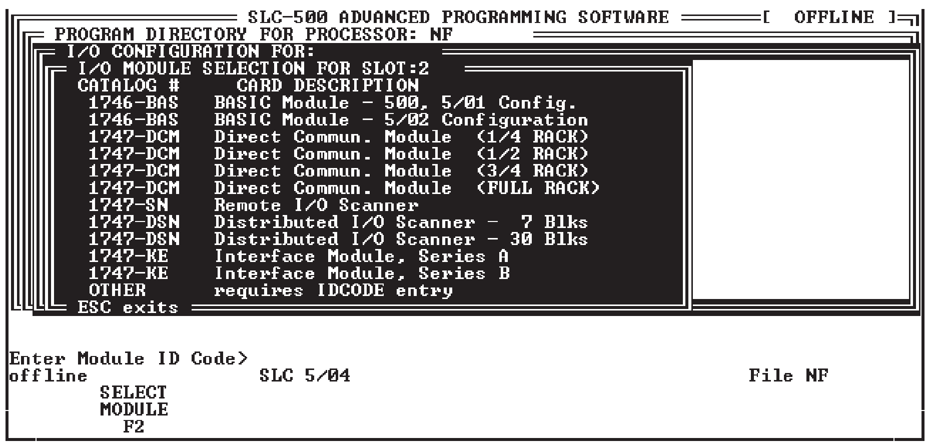
5. If using more I/O racks, repeat steps 3 and 4 for rack 2 followed by rack 3.

Important: At this point, the software does the following automatically:

- allocates slot numbers consecutively for the *configured set* of I/O racks. For example, slots 1-7 if you configured racks 1 and 2 at 4 slots each.
- places an asterisk (*****) next to each slot number configured in steps 3-5.

6. To designate the I/O module for the subject slot in the I/O rack, cursor to the subject slot number and press **`MODIFY SLOT [F5]`**.

The screen lists the types of I/O modules.



7. With **`[PAGE]`** and **`[↓] [↑]`** keys, cursor to the module type for the subject slot and press **`SELECT MODULE [F2].`**

The screen displays the module type in the row for the subject slot.

8. To assign I/O modules to remaining I/O slots, repeat steps 6 and 7.

9. If the subject I/O module is not listed (step 6), cursor to the bottom of the list and select `OTHER.` Then type the module ID code and press **`[ENTER].`**

ID code for 1746-FIO4I is 3224
ID code for 1746-FIO4V is 3218

The screen inserts the module ID code in the row for the subject slot.

10. After configuring your I/O, to exit press:

`EXIT [F8]`
`SAVE & EXIT [F8]`
You get the prompt: NEW ARCHIVE FILE CREATED

`SAVE TO FILE [F9]`
You get the prompt: NEW CONFIGURATION SAVED TO FILE

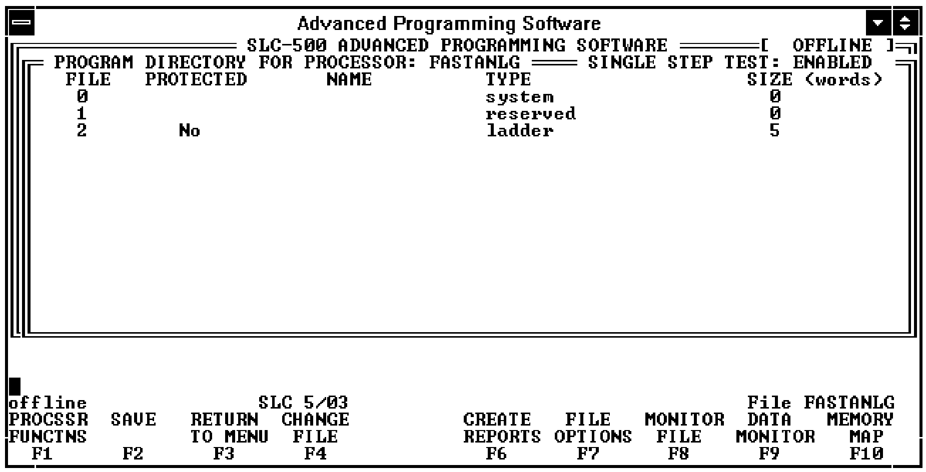
`ESC]`
`RETURN TO MAIN MENU [F3]`

Return to an Existing File

If you already created the program file for your application and want to add or edit ladder logic, return to it from the main menu screen as follows:

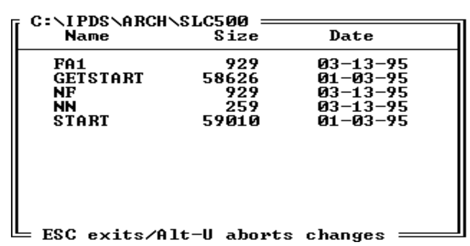
1. To return to a program file offline, press **`OFFLINE PRG/DOC [F3]`**.

You get the PROGRAM DIRECTORY FOR PROCESSORS screen.



2. Get the list of existing program files by pressing **`CHANGE FILE [F4].`**

You get a pop-up window with the list of existing program files.



3. Cursor to the file you want to open and press **`OFFLINE PRG/DOC [F1]`**.

The screen displays the name of the subject file in the header and removes the pop-up window.

4. To open the file so you can write or edit your ladder logic, press **`MONITOR FILE [F8]`**.

The screen displays the ladder logic of the subject program file.

5. To edit the logic, use function keys and follow the prompts as needed.

6. When finished programming, press **`EXIT [F3]`**.

7. If you want to save your work, press **`SAVE [F2]`**.
Then, follow the prompts and use function keys as needed to save the file.

Chapter 4

Processor and Module Considerations

This chapter describes concepts that you need to understand to program the fast analog I/O module in an SLC 500 system.

Processor Considerations

- processor update of analog I/O data
- monitoring analog I/O data
- addressing I/O image words

Module Considerations

- resolution of the module's I/O channel converters
- converting analog input data
- compute the analog input signal level
- converting analog output data
- compute the analog output signal level
- input channel filtering
- time delay for A/D conversion
- response to slot disable
- safe state for outputs
- module ID code

Processor Considerations

Knowing how the processor works helps you program it more effectively.

Processor Update of Analog I/O Data

Analog input and output image words are updated by the processor once every processor scan when the processor scans data and program files in succession.

Processor scan time depends largely on the size of your program files: the greater the number of programming instructions, the longer the time to scan the file. Some instructions take longer to scan than others. For information on processor scan time and instruction execution time, refer to appendices A and B of the Advanced Programming Software User Manual, publication 1747-6.4.

If an application requires processor updates of analog data more frequently than once per scan, use Immediate Input or Immediate Output instructions. These instructions typically update an analog channel in 1 millisecond, but also increase the overall scan time by the same amount.

Typical update times for SLC processors are:

- $\simeq$10 ms for a typical 1K program
- 1 ms per analog channel when using immediate I/O instructions

Monitoring Analog I/O Data

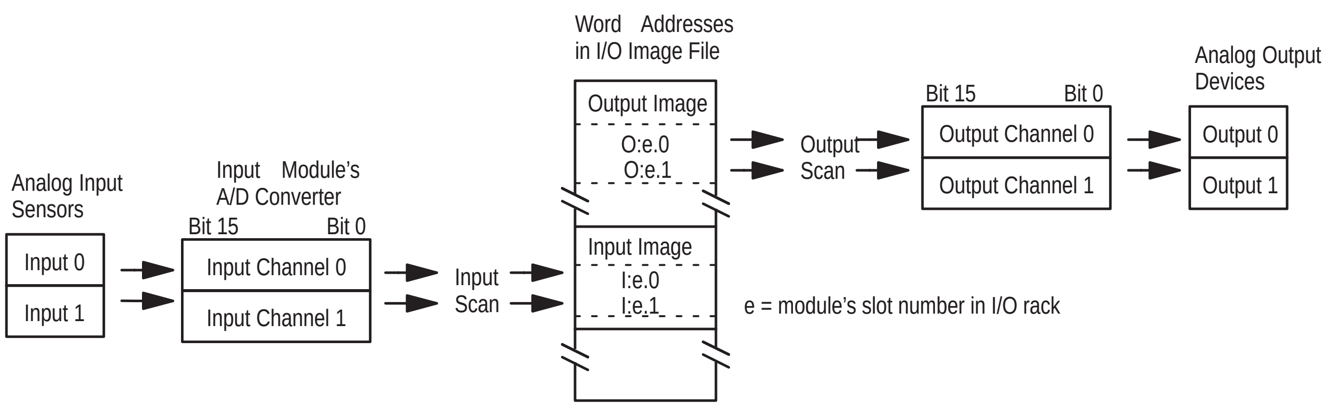
You can monitor analog input and output data in binary or decimal format with Advanced Programming Software (APS). You select the format by its radix. The default radix is binary. Binary data is presented in 2's-complement format (see appendix B). Changing the radix to decimal lets you view analog I/O data as decimal representations of integer words.

If you are using the Hand–Held Terminal (HHT) or the Data Table Access Module (DTAM™) to monitor analog I/O data, the binary radix is the only available option. To view analog I/O data in decimal, you must program the movement of data to an integer file and view it there.

Addressing I/O Image Words

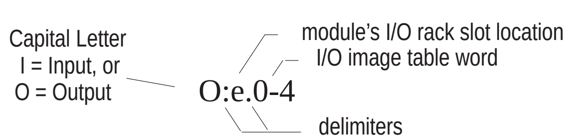
Each module input channel is addressed as a single word in the processor's input image table and each module output channel is addressed as a single word in the processor's output image table. The module use a total of 2 input words and 2 output words (Figure 4.1).

Figure 4.1
Processor I/O Image Words Used by the Module



The converted input values from input channels 0 and 1 are addressed as words 0 and 1 of the slot where the module resides. The output values for the output channels 0 and 1 are addressed as output words 0 and 1 of the slot where the module resides.

Example – You would address the output image word for output O, word 0, in slot 3 as: O:3.0 where delimiters : and . must be placed as shown.



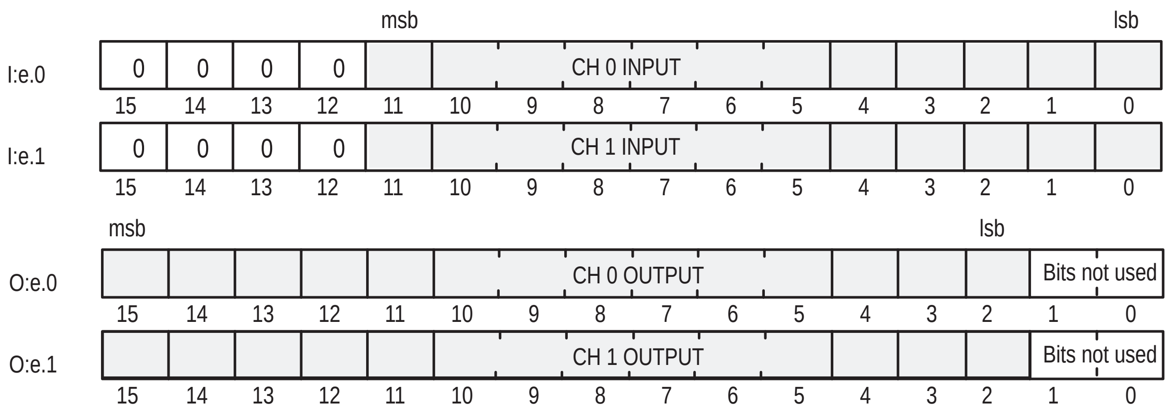
Module Considerations

The module's I/O channel converters affect resolution of I/O data and bit usage in I/O image words. We show you how to compute I/O signal levels. Input filtering and input A/D conversion affect input response time.

Data Resolution of the Module's I/O Channel Converters

The module's I/O channel converters limit bit usage to less than a full 16-bit word when converting analog to digital input data and digital to analog output data. Bit maps (Figure 4.2) show resulting digital data storage in input and output image words.

Figure 4.2
Bit Usage for I/O Channel Converters



e = module's slot number

The input channel converter resolution is 12 bits, where the highest four bits are always zero. The usable range of the channel word is 0-4095.

The output channel converter resolution is 14 bits, where the lowest two bits are not used. They have no effect on the output value.

Important: The module left-justifies the 14-bit data (lsb @ bit 2) in the output channel word. This reduces the output resolution to:

- 2.56348 µA/LSB for current outputs
- 1.22070 mV/SLB for voltage outputs

Converting Analog Input Data

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

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

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

Compute the Analog Input Signal Level

To determine what the analog input signal level (sensor signal) should be for a given decimal value in the input image table, compute it as follows:

$$\text{Sensor Signal} = \frac{\text{Full Scale Input}}{\text{Full Scale Count}} \times \text{Input Image Value}$$

For voltage inputs, a full scale input of 10V dc has a full scale count of 4095 and a full scale input of 5V dc has a full scale count of 2047. Either way:

$$\text{Sensor Signal} = 2.44\ \text{mV/count} \times \text{Input Image Value}$$

For current inputs, a full scale input of 20 mA has a full scale count of 2047.

$$\text{Sensor Signal} = 0.00977\ \text{mA/count} \times \text{Input Image Value}$$

For example, if the input image table value is 409 from a 4-20 mA sensor:

$$\text{Sensor Signal} = \frac{\text{Full Scale Input}}{\text{Full Scale Count}} \times \text{Input Image Value} = 0.00977 \times 409 = 4\ \text{mA}$$

Converting Analog Output Data

The module converts 16-bit binary values from the output image table to 14-bit analog output signals and left-justifies the bit code in the channel word. The output range, decimal representation for the output range, number of significant bits, and converter resolution are as follows:

Module	Output Range	Decimal Representation (output image table)	Significant Bits	Resolution
FIO4I	0 to 21 mA – 1LSB	0 to +32,764	13 bits	2.56348 μA/LSB
	0 to 20 mA	0 to +31,208	12.92 bits	
	4 to 20 mA	6,242 to 31,208	12.6 bits	

FIO4V	–10 to +10V dc – 1LSB	–32,768 to +32,764	14 bits	1.22070 mV/LSB
	0 to 10V dc – 1LSB	0 to 32,764	13 bits	
	0 to 5V dc	0 to 16,384	12 bits	
	1 to 5V dc	3,277 to 16,384	11.67 bits	

Compute the Analog Output

Compute the output image table value (decimal representation) required for a desired analog output signal level (to the output device) as follows:

$$\text{Output Image Value} = \frac{\text{Full-scale Decimal Representation}}{\text{Full Scale Output}} \times \text{Desired Signal Level}$$

Example for a Current Output
If the module's output range is 4-20 mA and you want to set the output to 4 mA, compute the output image value as follows:

$$\text{Output Image Value} = \frac{31{,}208}{20\text{ mA}} \times 4\text{ mA} \simeq 6242$$

Important: The actual resolution for analog current outputs is 2.56348 µA/LSB, where the 14-bit decimal representation is left justified as follows:

15 (msb)	14	13	12	11	10	9	8	7	6	5	4	3	2 (lsb)	1	0
					CHANNEL OUTPUT WORD									bits not used	

Example for a Voltage Output
If the module's output range is 1-5V dc and you want to set the output to 1V dc, compute the output image value as follows:

$$\text{Output Image Value} = \frac{16{,}384}{5\text{V dc}} \times 1\text{V dc} \simeq 3277$$

Important: The actual resolution for analog voltage outputs is 1.22070 mV/LSB, where the 14-bit decimal representation is left justified as follows:

15 (msb)	14	13	12	11	10	9	8	7	6	5	4	3	2 (lsb)	1	0
					CHANNEL OUTPUT WORD									bits not used	

Input Channel Filtering

The module's input filters are designed to attenuate less than 1% of the input signal in the 0 to 1000 Hz range (Figure 4.3). The –3dB point is approximately 7000 Hz (Figure 4.4). The input filter causes a signal delay of approximately 100us. The module's A/D converter sees a 95% step change of an input signal in that time.

Figure 4.3
Percent of Signal Passed

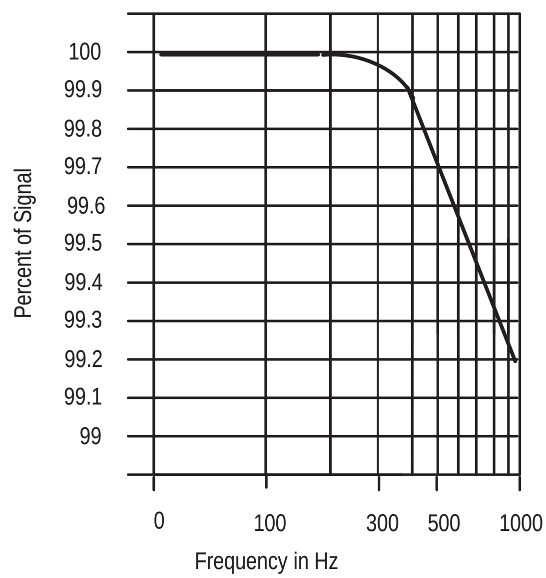
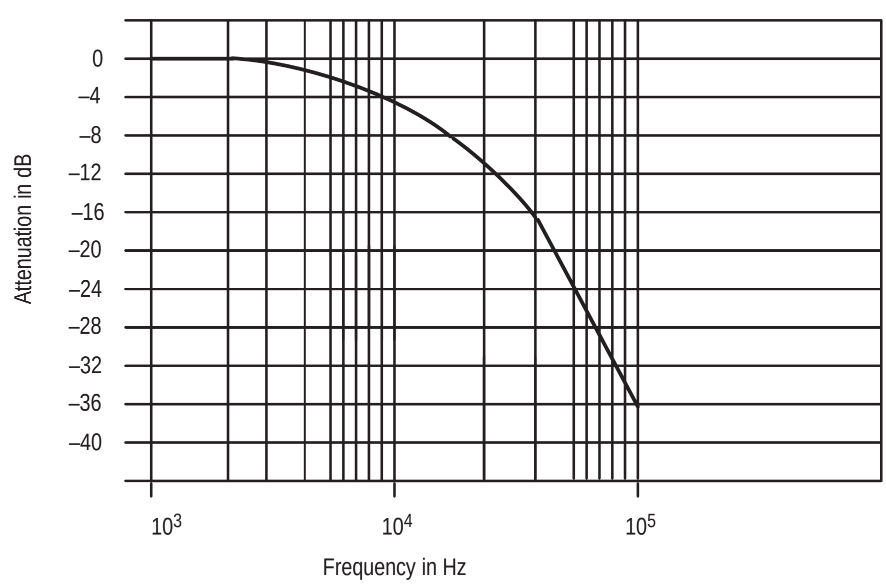


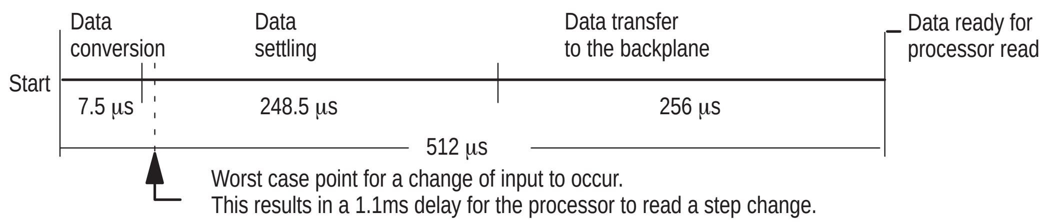
Figure 4.4
Input Channel Frequency Response



Time Delay for A/D Conversion

The A/D converter uses 7.5 µs for data conversion, 248.5 µs for data settling, and 256 µs for data transfer to the backplane. New data is available in 512 µs cycles (Figure 4.5).

Figure 4.5
Response Time of A/D Converter



The worst-case specification for the SLC processor to read a step change is 1.1ms between readings. This is true for a step change occurring just after data conversion (first 7.5 µs of the 512 µs cycle). In this case, the read cycle cannot begin until the next data conversion.

Important: Do not attempt to read data from the module more often than once every 512 µs. If you do, the module may not be able to update new data.

Response to Slot Disable

You can disable any I/O rack slot by means of a processor function. For more information, refer to APS Reference Manual, publication 1747-6.11. Before disabling a slot containing an analog I/O module, be aware of the implications.

ATTENTION: Clearly understand the safety implications of disabling an analog module slot before doing it.

Input Response to Slot Disable

The module continues to update its inputs for transfer to the processor, but the processor:

- does not read inputs from the module in a disabled slot
- retains the last-state input image table values
- upon re-enabling the slot, reads current inputs in the subsequent scan

Output Response to Slot Disable

While the module holds its outputs in their last state, the processor:

- may update its output image table
- does NOT transfer output image table values to the module
- upon re-enabling, transfers the current output image in the subsequent scan

Safe State for Outputs

Whenever an SLC 500 system is *not* in RUN mode, the analog module's outputs are automatically forced to 0 volts or 0 milliamps by the SLC 500 system. This occurs when the processor is in one of the following modes:

- FAULT
- PROGRAM
- TEST

ATTENTION: When designing and installing the SLC 500 system, place devices connected to analog output channels in a safe state whenever the analog output is zero (± the offset error). Determine which output conditions must be held ON for a safe state.

Module ID Code

You must enter the ID code if your revision of APS software does not include the subject I/O module in its list of modules, displayed when you "modified the slot" during the configuration procedure that you completed in chapter 3.

ID code for FIO4I is 3224
ID code for FIO4V is 3218

Chapter 5

Writing Ladder Logic

This chapter presents the following programming examples;

- Retentive and Non-Retnetive Programming
- Detect an Out-of-range Input
- Scale Analog Inputs and Detect an Out–of–Range Condition
- Scale Analog Outputs
- Scale Offsets when > 32,767 or < –32,768
- Scale and Range-check Analog Inputs and Outputs
- PID Control with Analog I/O Scaling

Important – We present programming examples for instructional purposes only. Because of the many variables and requirements associated with any application, the Allen–Bradley Company cannot assume responsibility or liability for actual use based on these examples.

Retentive and Non-retentive Programming

The processor's automatic response for scanning the I/O image table is described below for the following conditions:

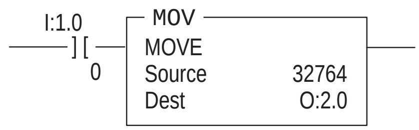
For these conditions:	the processor:
• mode is switched to Program • power is turned OFF	retains the last values in the I/O image table.
• mode is switched to Run • power is turned ON	transfers output image data to the module and input image data from the module
• processor detects a *minor* fault	resets analog outputs to zero, but retains output image values
• fault condition is corrected	transfers output image data to the module

We give you the following examples for programming a different response.

- retain an analog output
- non-retentive analog output
- clear the output for changing mode or cycling power

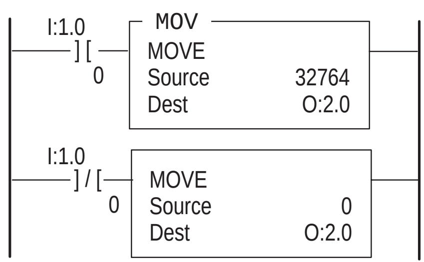
Retain an Analog Output

This example loads a program constant into an analog output channel. Consider a digital I/O module in slot 1, and an analog I/O module in slot 2. When bit 0 of the digital I/O module is set, the rung is true, and the full-scale value of 32,764 is moved into the output image table location corresponding to slot 2, analog output channel 0. At the end of the scan, the value is transferred to the module and converted to a corresponding full-scale voltage or current output.



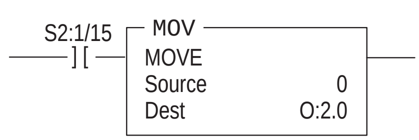
Non-retentive Analog Output

This example loads a program constant into an analog output channel and clears it, based on logical conditions. Consider a digital I/O module in slot 1, and an analog I/O module in slot 2. When bit 0 is set in word 0 of the digital I/O module, the first rung is true and the full-scale value of 32,764 is transferred to channel 0. When the bit is reset to zero, the second rung is true, and the value of zero is transferred to the channel.



Clear the Output for Changing Mode or Cycling Power

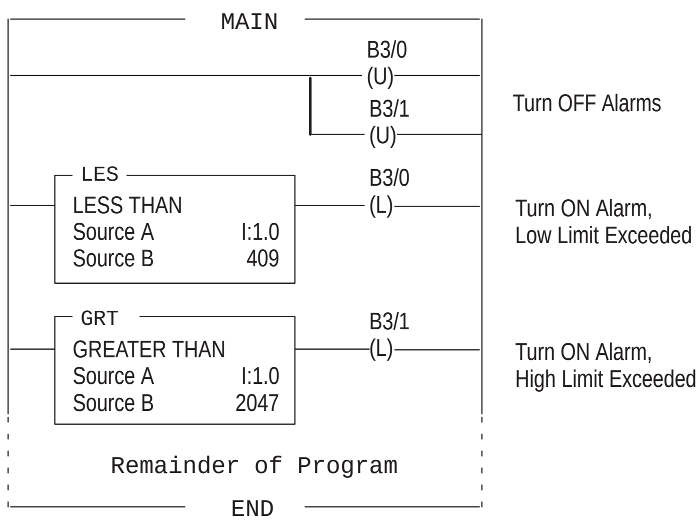
This example clears analog output channel 0 during the initialization scan (first processor scan). The first pass bit, S2:1/15, in the Status File is used to initialize the analog output at power up in RUN mode or upon setting the processor to RUN or TEST mode. This bit goes ON automatically only for the first-pass scan. To clear another analog output channel, use another rung with a different MOV destination address. The analog module is in slot 2.



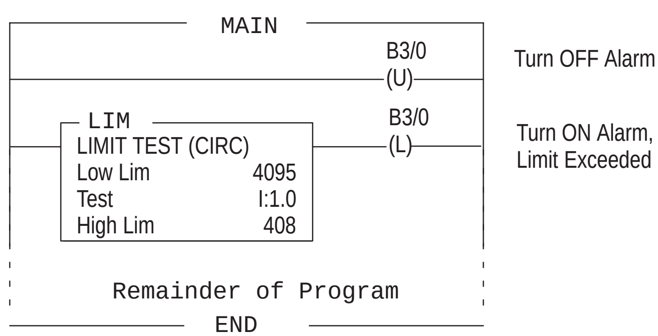
Detect an Out-of-range Input

Analog modules do not provide an input out–of–range signal to the processor. However, if this feature is critical to a specific application, you can program the processor to provide this function.

The following program applies to all SLC 500 processors. It uses comparison instructions (LES and GRT) to check for analog input values which exceed low and high limits respectively. Whenever this happens, the program latches a bit that could serve to trigger an alarm elsewhere in your ladder program. In this example, the input range is 1-5V dc (decimal range of 409-2047).



We present an alternative program for SLC 5/02 (and later) processors. It uses a single Limit Test instruction that checks low and high limits. Whenever the input value exceeds a limit, this program latches a bit that could trigger an alarm elsewhere in your ladder program. In this example, the input range is 0 to 10V dc (decimal range of 0-4095). If the input range were 4-20 mA, the low and high limits would be 2047 and 408, respectively.



In both examples, the analog input value is in word 0 of slot 1 (I:1.0).

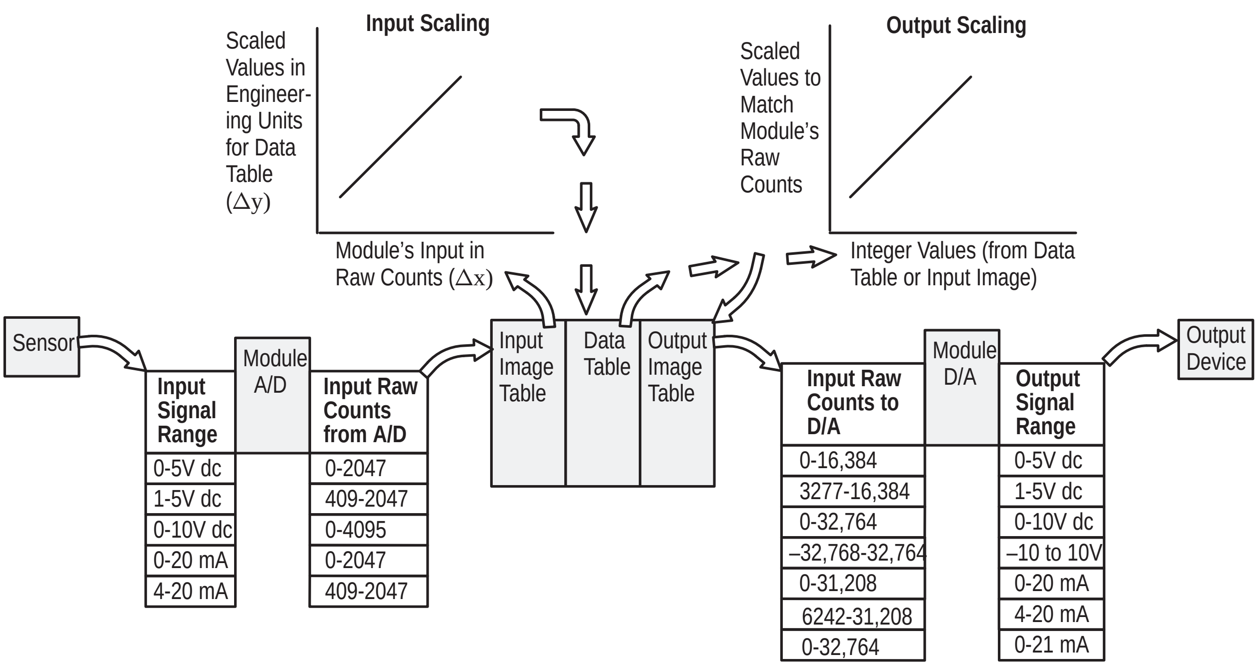
Overview of Scaling Inputs and Outputs

Scaling is the application of a ratio on the the variable to be scaled, where the ratio is the scaled range (Δy) to the input range (Δx).

The purpose for scaling values when programming analog I/O modules is to change data format.

When you scale:	You start with this data format:	And typically change the format to:
inputs	decimal input range in raw counts (from the module's A/D converter)	engineering units such as PSI (stored in the data table)
outputs	integer values from the data table (or from the input image table)	decimal output range in raw counts to match the module's output range
on a linear graph	Δx	Δy

We illustrate input and output scaling, the source and type of data to be scaled, and the type and destination of the scaled data as follows:



You scale data with ladder logic using arithmetic instructions such as add, multiply, and double divide; or by using the scaling instruction available with SLC 5/02 (or later) processors. The scaling computation is as follows:

Scaled value = (Input value x Slope) + Offset
Slope = Δy / Δx = scaled range / input range
= (scaled max. – scaled min.) / (input max. – input min.)
Offset = scaled min. – (input min. x slope)

In this context, the input value and input range are inputs to the scaling function, not necessarily inputs associated with the sensor input.

Scale an Analog Input and Detect an Out-of-range Condition

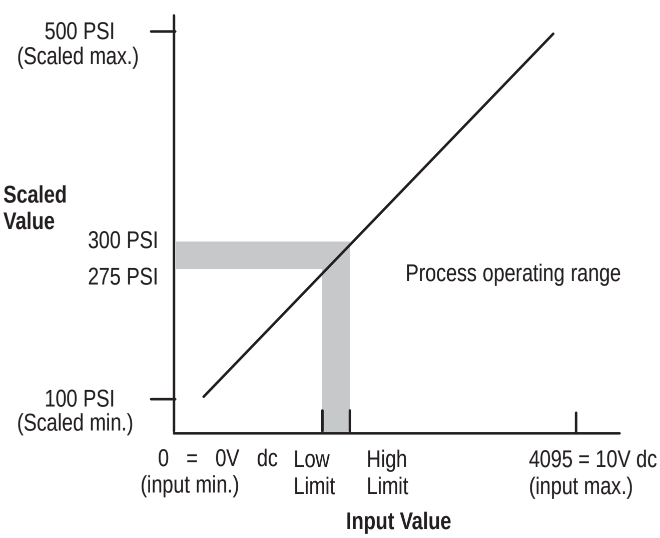
The following example shows input range checking and scaling the analog input to engineering units for an FIO4V analog input module.

We are making the following assumptions:

- The FIO4V is located slot 3 of a modular system.
- A pressure sensor with a 0-10V dc output is wired to input channel 1.
- The sensor signal voltage is proportional to a range of 100-500 PSI.
- The process pressure must stay between 275 and 300 PSI. (If the pressure deviates from this range, your logic sets an alarm bit.)
- Data is presented in PSI for monitoring and display purposes.

Input Scaling

The scaling operation is displayed in the following graph. It displays the linear relationship between the input and the resulting scaled values.



Calculating the Linear Relationship

Use the following equations to express the linear relationship between the input value and the resulting scaled value.

Scaled value = (input value x slope) + offset

Slope = (scaled max. – scaled min.) / (input max. – input min.)
(500 – 100) / (4095 – 0) = 400/4095 = 0.0977

Offset = scaled min. – (input min. x slope)
100 – (0 x (400/4095) = 100

Scaled value = [input value x (0.0977)] + 100

Calculating the Out–of–Range Limits

Use the following equation to compute low and high out–of–range limits.

Input value = (scaled value – offset) / slope

low limit: (275 – 100) / (0.0977) ≃ 1750 counts

high limit: (300 – 100) / (0.0977) ≃ 2750 counts

Ladder Logic

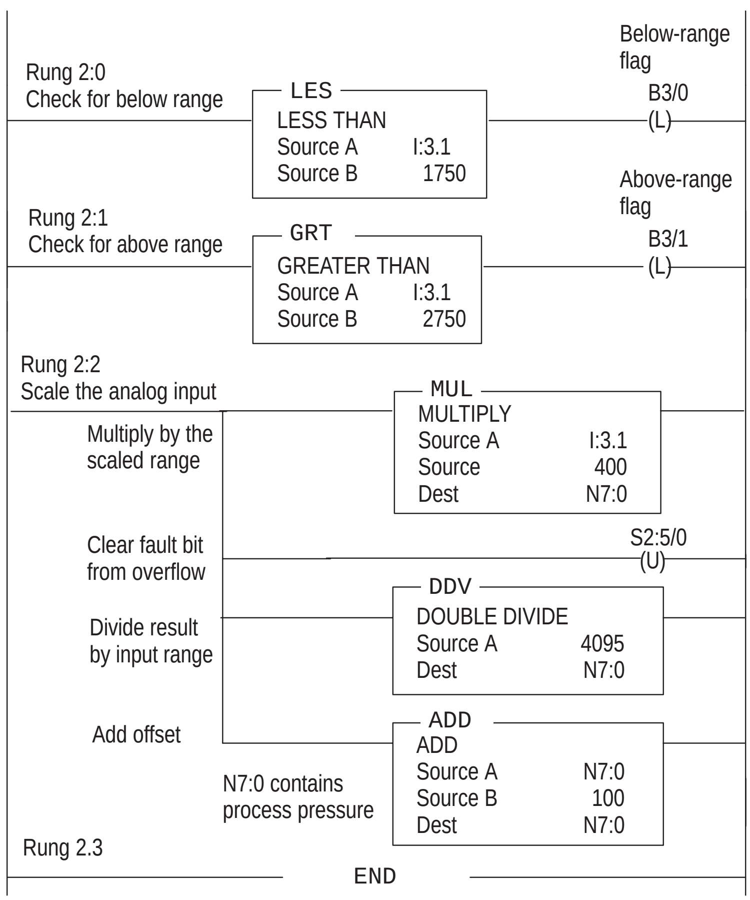
We present two examples for programming the processor.

The first example uses standard math instructions available in any SLC 500 processor. This ladder logic prevents a processor fault by unlatching the mathematical overflow bit S2:5/0 before the end of the scan.

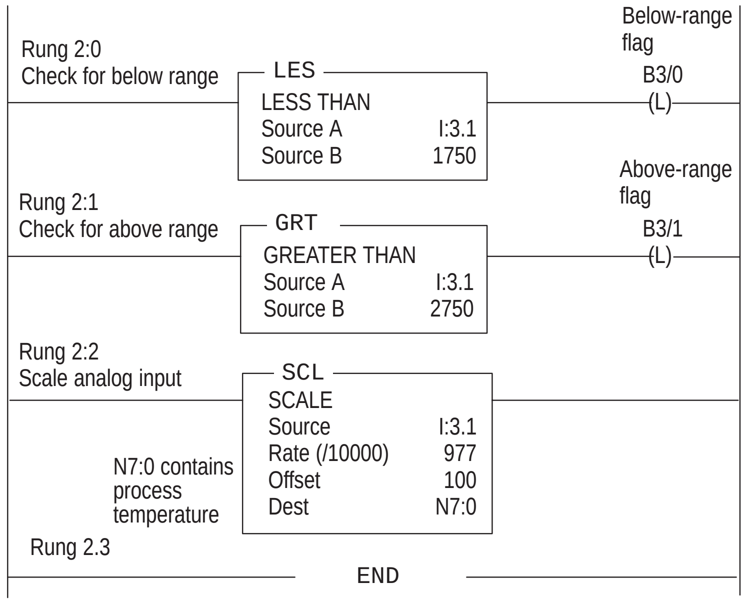
The second example uses the scaling instruction (SCL) available in SLC 5/02 (and later) processors. The rate parameter is calculated by multiplying the slope by 10,000. If the *slope* exceeds 3.2767, you *cannot* use the SCL.

rate = (400/4095) x 10,000 = 977 (The slope is 0.0977 so you can use the SCL instruction.)

Standard Math Example



Example Program Using the Scaling Instruction (SCL)



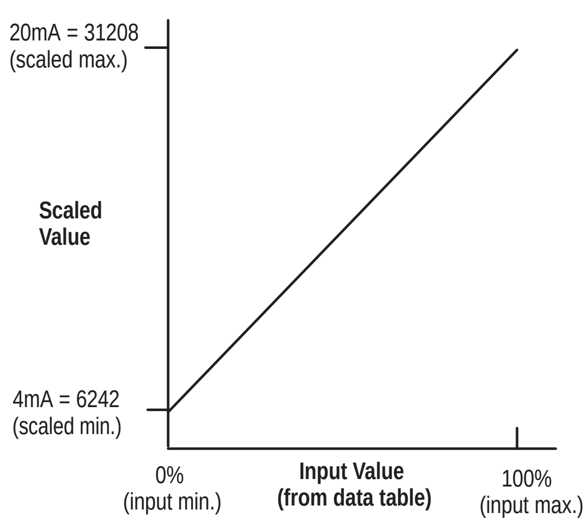
Scale an Analog Output

The following example shows the scaling of analog output values to engineering units for monitoring or controlling purposes.

We are making the following assumptions:

- The FIO4I is located in slot 2 of a SLC 500 system.
- An actuator of a flow control valve is wired to output channel 0.
- The actuator accepts a 4-20 mA signal for a 0-100% of valve opening.
- The actuator can not receive a signal out of the 4-20 mA range.
- The percentage of valve opening is manually input to the SLC.

The following graph displays the linear relationship.



Calculating the Linear Relationship

Use the following equations to compute the scaled output value:

Scaled value = (input value x slope) + offset

Slope = (scaled range) / (input range)
= (scaled max. – scaled min.) / (input max. – input min.)
= (31208– 6242) / (100–0) = 24966/100
The slope is greater than 3.2767 so you cannot use SCL instruction.

Offset = scaled min. – (input min. x slope)
= 6242 – [0 x (24966 / 100)] = 6242

Scaled value = [input value x 24966 / 100] + 6242

Ladder Logic

The out-of-range limits are predetermined because any value less than 0% is 6242 and any value greater than 100% is 31,208. The ladder logic checks for out-of-range limits to verify that not less than 4 mA and not more than 20 mA is delivered to the analog output channel.

The percentage of valve opening may be entered into processor memory by:

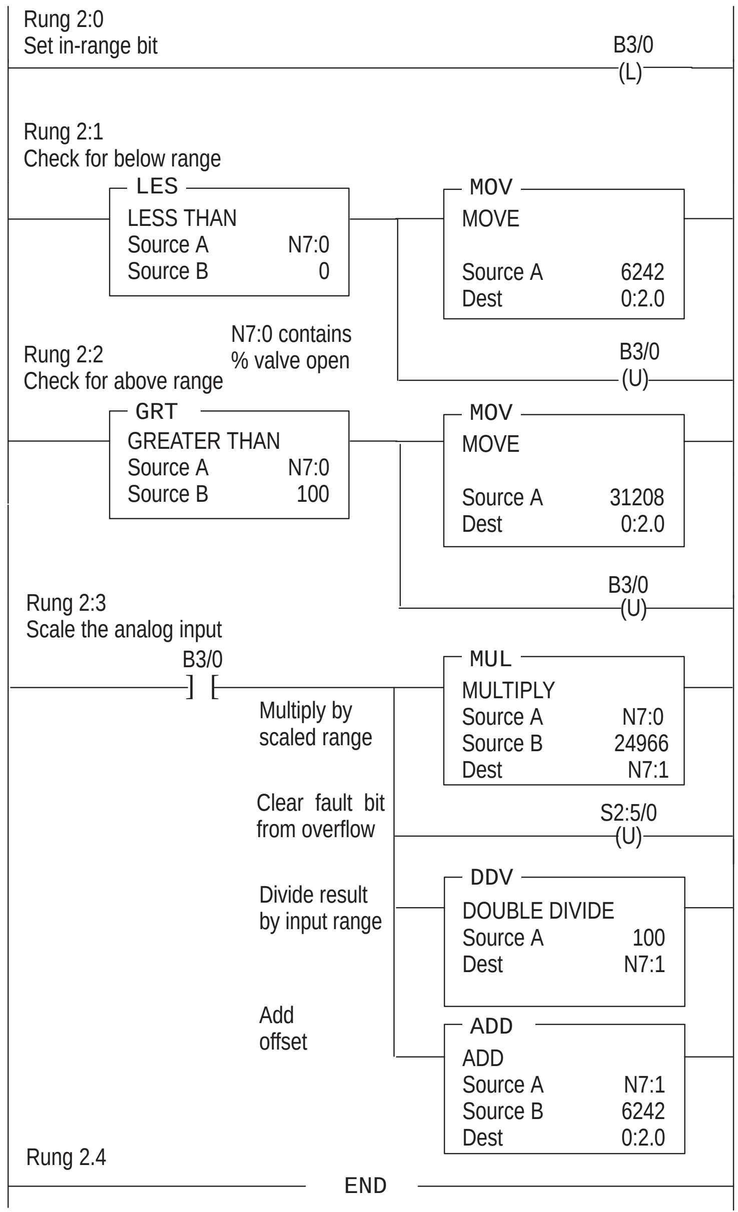
- entering the data through a DTAM or HHT
- MOVing the data from a keypad

The percentage of valve opening may be displayed for operator interface by:

- monitoring the data using a DTAM or HHT
- MOVing the data through the output module to a Dataliner
- converting the data to BCD and MOVing it to an LED display

The following ladder logic uses standard math. It unlatches the mathematical overflow bit S2:5/0 before the end of the scan to prevent a processor fault.

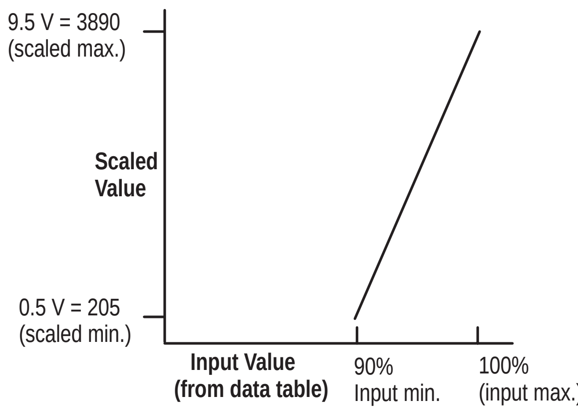
Example Program for Any SLC Processor



Scale Offsets When >32,767 or <32,768

Some applications may produce an offset greater than 32,767 or less than –32,768, the largest value that can be stored in a 16-bit integer or processed by an SLC processor. If so, you may reduce the magnitude of the offset by shifting the linear relationship along the input value axis. When you compute linear relationships, you will see how the offset is reduced in this manner. The following example applies to a 0.5-9.5V dc output scaled from a narrow input range of 90-100%.

1. First we compute linear relationships and observe that the offset is beyond –32,768.



Use the following equations to compute linear relationships:

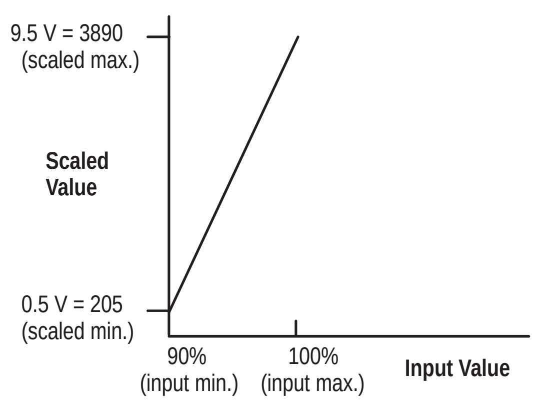
Scaled value = (input value x slope) + offset

Slope = (scaled max. – scaled min.) / (input max. – input min.)
(3890 – 205) / (100 – 90) = 3685/10 ≃ 369 (> 3.2767 so you cannot use SCL)
Offset = scaled min. – (input min. x slope)
205 – [90 x (368.5] = 205 – 33165 = **–32,960**

Scaled value = (input value) x (368.5) – 32,960

Notice the offset is beyond –32,768.

2. Then we shift the linear relationship along the input value axis.



3. Now we compute the offset for the shifted linear relationship.

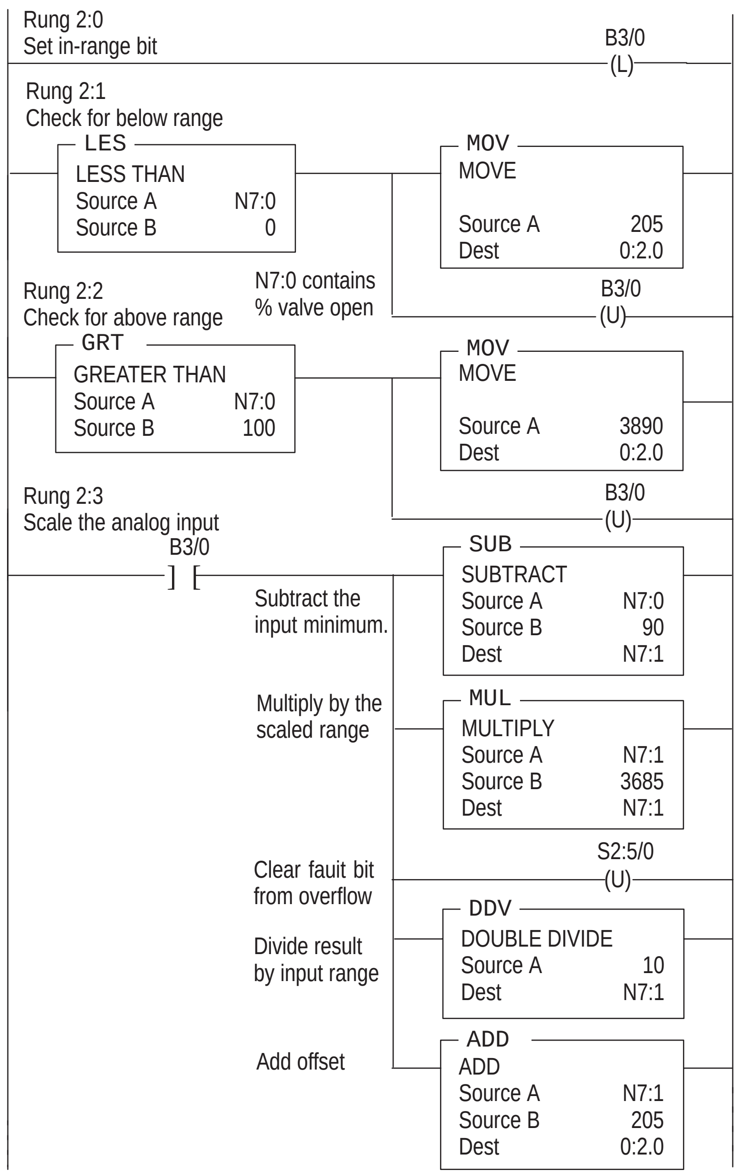
Offset = scaled min. – (input min. x slope)
= 205 – [0 x (368.5] = **205**

The offset is 205, well below 32,767. The slope remains 3685/10 (> 3.2767), so you cannot use the SCL instruction for scaling.

Slope = (scaled range.) / (input range) = (3890 – 205) / 10 = 3685/10
Scaled value = (input value x slope) + offset = [input value x 3685 /10] + 205

Ladder Logic

The following ladder logic uses standard math. It unlatches the mathematical overflow bit S2:5/0 before the end of the scan to prevent a processor fault. The module is located in slot 2, and the output device is wired to channel 0.

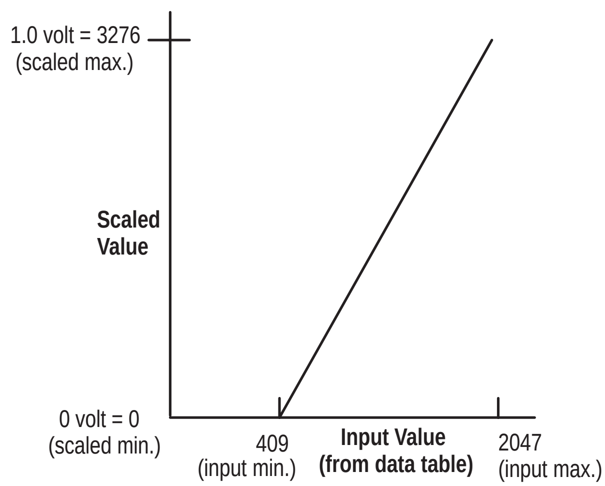


Range-check an Analog Input and Scale It For an Output

This example checks the range of an analog input and scales it for use as an output. An FIO4V is placed in slot 1 of an SLC 500 system. A 4-20 mA signal representing 0-200 PSI from a pressure sensor is delivered to input channel 0. The input value is checked to ensure it remains within range. If the ladder logic detects an out–of–range condition, it sets a flag bit.

The input signal is then scaled and delivered as a 0-1.0 volt output signal to a panel pressure meter connected to output channel 0.

The graph displays the linear relationship between the analog input signal and the 0-1.0 output signal delivered to the panel pressure meter.



Calculating the Linear Relationship

Use the following equations to compute the linear relationship between the input values (from the input image table) and resulting scaled values for the 0-1V output:

Scaled value = (input value x slope) + offset

Slope = (scaled max. – scaled min.) / (input max. – input min.)
(3276 – 0) / (2047 – 409) = 3276 / 1638 = 2.0
Since the slope is less than 3.2767, you can use the SCL instruction.

Offset = scaled min. – (input min. x slope)
0 – (409 x 2) = –818

Scaled value = (input value x 2) – 818

Ladder Logic

We present two examples. The first runs on any SLC 500 processor. The second uses the scaling instruction available on SLC 5/02 (and later) processors.

In the first example, the analog input value is checked against the minimum and maximum input limits. B3:0/0 is the in-range flag bit.

If the input is out of range, the in-range flag bit is reset and the output is set to its minimum or maximum limit. If the input is in range, the output value is determined by scaling the input.

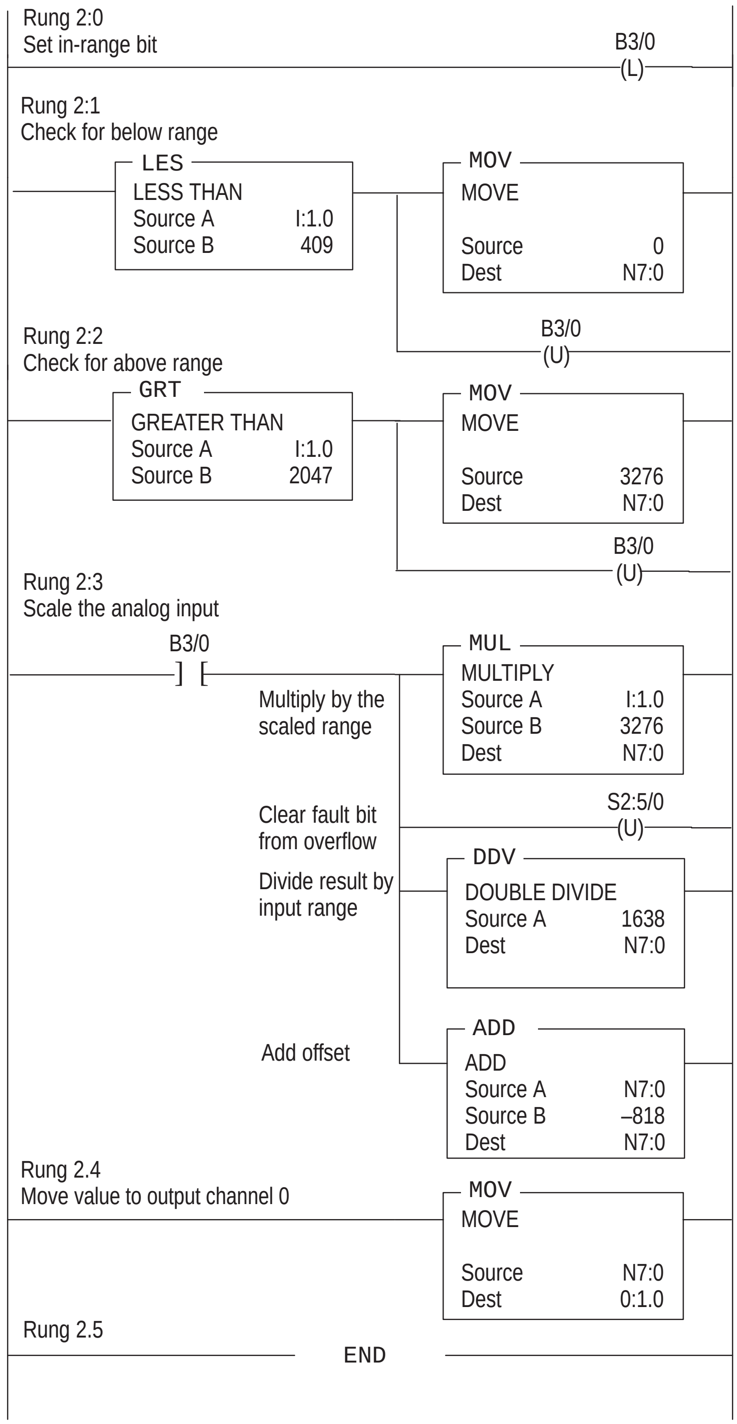
To scale an analog input for this example, follow these steps:

1. Multiply the input by the scaled range
   Scale range = (scaled max. – scaled min.) = 3276 – 0 = 3276
2. Divide the 32 bit result by the input range
   Input range = (input max. – input min.). = 2047 – 409 = 1638
3. Add the offset value (in this case negative) = –818
   Move the final value to the analog output channel 0.

In this example, the multiply operation generates an overflow bit and minor error flag whenever the result exceeds 16 bits. Since the divide operation uses a 32-bit result in the math register, the overflow is no problem. The minor error flag has to be cleared before the end of the program scan to avoid a system error.

Refer to the ladder program on the next page.

Example Program for Any SLC Processor

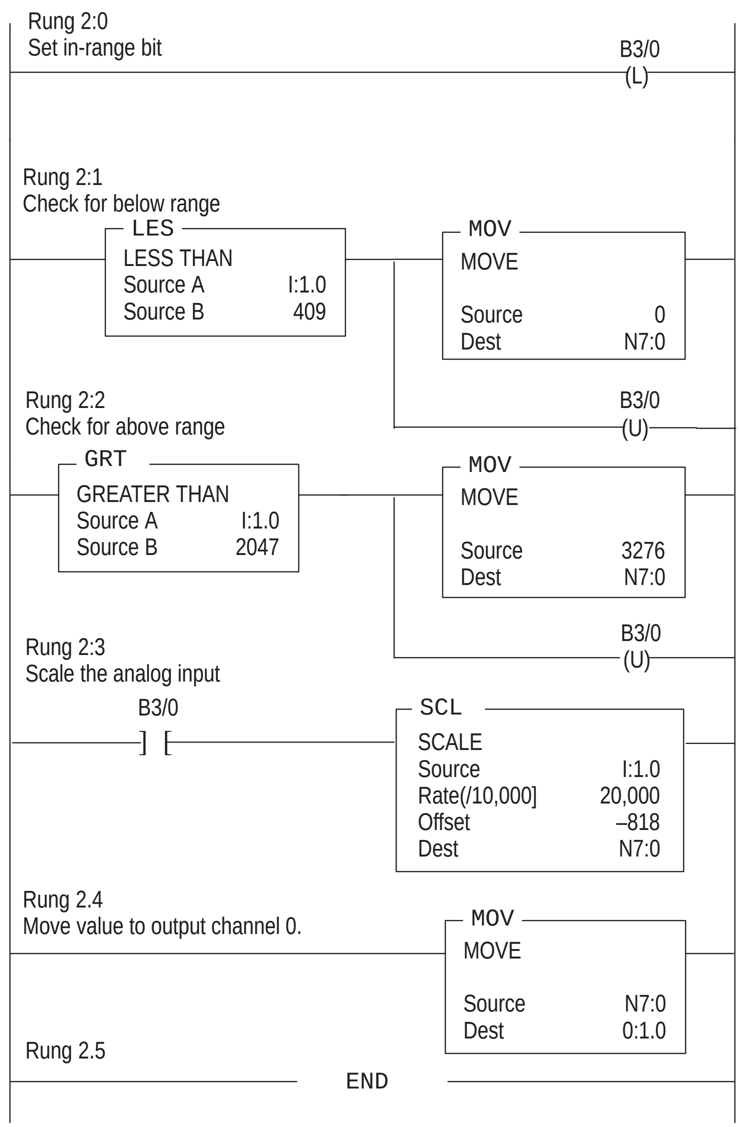


Example Program For SLC 5/02 (or later) Processors

Using the scaling instruction (SCL) requires less ladder logic. The SCL instruction uses the same multiply, divide, and add algorithm but it does so with a single rate instead of using scaled range and input range values. The rate is determined by:

Rate = slope x 10,000
= (scale range / input range) x 10,000
= 3276 / 1638 x 10,000
= 2 x 10,000
= 20,000

If the slope was greater than 3.2767, you could not use the SCL instruction because the rate would exceed 32,767, a value too large to handle.



PID Control With Analog I/O Scaling

With the combination of PID and SCL (scale) instructions or PID and standard math instructions, you can write and display ladder logic in engineering units such as PSI or ºC. Do this as follows:

1. Scale the analog input PV by calculating the slope (or rate) of the analog input range. For example, an input range such as 1-5V dc has a corresponding scaled range of 409-2047. You would scale the 409-2047 against 0-16383 for a slope of 10 (SCL rate of 100,000).

Important: You cannot use the SCL instruction for scaling inputs if input rates (slope x 10,000) are too large (exceed 32,767). You must use standard math instructions, instead.

2. Scale the analog output CV by calculating the slope (or rate) of the analog output range. For example, an output range such as 4-20 mA has a corresponding decimal (scaled) range of 6242-31208. You would scale the 6242-31,208 against 0-16,383.

For this output range:	Compute the slope as follows:	Compute offset as follows:
4-20 mA	$\frac{\text{scaled max} - \text{scaled min}}{\text{input max} - \text{input min}}$ $\frac{31208 - 6242}{16383 - 0} = \frac{24966}{16383} = 1.5238$	scaled min – [input min x slope] = 6242 – [0 x 1.5238] = 6242

Here are some useful rate and offset parameters for the SCL instruction when scaling analog output ranges:

SCL Parameter	0-20 mA	4-20 mA	0-5 V dc	1-5 V dc	0-10V dc
Rate (slope x 10,000)	19,049	15,239	10,000	8,000	19,999
Offset	0	6242	0	3277	0

3. Enter PID parameters in engineering units into the PID instruction. For example, if the 4-20 mA analog input range represents 0-300 PSI, enter 0 as the minimum (Smin) and 300 as the maximum (Smax). You can also enter setpoints and deadband in engineering units. The data monitor screen for PID will display its parameters in the same engineering units.

Ladder Logic

We present two examples of PID control logic with analog I/O scaling for use on an SLC 5/02 (or later) processor:

- scaled voltage input and output, 0-10V dc
- scaled current input and output, 4-20 mA

Example Program For SLC 5/02 (or later) Processors
(scaled voltage input and output)

```
Rung 2:0
|                                                    +IIM--------------------+ |
|----------------------------------------------------+IMMEDIATE INPUT w MASK +-|
|                                                    |Slot              I:1.0| |
|                                                    |Mask               FFFF| |
|                                                    |Length                1| |
|                                                    +-----------------------+ |

Rung 2:1
|                                                         +MUL---------------+ |
|---------------------------------------------------------+MULTIPLY          +-|
|                                                         |Source A     I:1.0| |
|                                                         |                  | |
|                                                         |Source B         4| |
|                                                         |                  | |
|                                                         |Dest          N7:0| |
|                                                         |                 0| |
|                                                         +------------------+ |

Rung 2:2
|                                                    +PID--------------------+ |
|----------------------------------------------------+PID                    +-|
|                                                    |Control Block     N10:0| |
|                                                    |Process Variable   N7:0| |
|                                                    |Control Variable N10:29| |
|                                                    |Control Block Length 23| |
|                                                    +-----------------------+ |

Rung 2:3
|                                                         +SCL---------------+ |
|---------------------------------------------------------+SCALE             +-|
|                                                         |Source      N10:29| |
|                                                         |                 0| |
|                                                         |Rate[/10000] 19999| |
|                                                         |                  | |
|                                                         |Offset           0| |
|                                                         |                  | |
|                                                         |Dest         O:1.0| |
|                                                         |                  | |
|                                                         +------------------+ |

Rung 2:4
|                                                    +IOM--------------------+ |
|----------------------------------------------------+IMMEDIATE OUT w MASK   +-|
|                                                    |Slot              O:1.0| |
|                                                    |Mask               FFFF| |
|                                                    |Length                1| |
|                                                    +-----------------------+ |

Rung 2:5
|                                                                              |
|------------------------------------+END+-------------------------------------|
|                                                                              |
```

Example Program For SLC 5/02 (or later) Processors
(scaled current input and output)

```
Rung 2:0
|                                                     +IIM--------------------+ |
|-----------------------------------------------------+IMMEDIATE INPUT w MASK +-|
|                                                     |Slot             I:1.0| |
|                                                     |Mask              FFFF| |
|                                                     |Length               1| |
|                                                     +----------------------+ |

Rung 2:1
Scale the analog input with math instructions.
|                                                       +MUL---------------+     |
|--------------------------------------------+---------+MULTIPLY          +-+--|
|                                            |         |Source A     I:1.0| |   |
|                  Multiply by scaled range  |         |                  | |   |
|                                            |         |Source B     16383| |   |
|                                            |         |                  | |   |
|                                            |         |Dest          N7:0| |   |
|                                            |         +------------------+ |   |
|                                            |                              |   |
|                                            |                        S2:5  |   |
|                  Clear overflow fault bit  +-------------------------(U)--+   |
|                                            |                           0  |   |
|                                            |                              |   |
|                                            |         +DDV---------------+ |   |
|                     Divide by input range  +---------+DBL DIVIDE        +-+--|
|                                            |         |Source A      1638| |   |
|                                            |         |                  | |   |
|                                            |         |                  | |   |
|                                            |         |Dest          N7:0| |   |
|                                            |         +------------------+ |   |
|                                            |                              |   |
|                                            |         +ADD---------------+ |   |
|                                Add offset  +---------+ADD               +-+--|
|                                                      |Source A      N7:0|     |
|                                                      |                  |     |
|                                                      |Source B     -4091|     |
|                                                      |                  |     |
|                                                      |Dest          N7:0|     |
|                                                      +------------------+     |
```

Brake Monitor
Example Program For SLC 5/02 (or later) Processors

```
Rung 2:2
The next 2 rungs ensure that the analog input value to be scaled remains within
the limits of 409 and 2047.  This prevents out-of-range conversion errors in
the SCL and PID instructions.  The latch bits can be used elsewhere in the
program to identify the particular out-of-range error which occurred.
|                                                        Under                  |
|                                                        Range                  |
| +LES---------------+                                       B3                 |
|-+LESS THAN         +--------------------------------+----(L)---------------+-|
| |Source A      N7:0|                                |       0              | |
| |                 0|                                |                      | |
| |Source B       409|                                | +MOV---------------+ | |
| |                  |                                +-+MOVE              +-+ |
| +------------------+                                  |Source A       409|   |
|                                                       |                  |   |
|                                                       |Dest          N7:0|   |
|                                                       |                 0|   |
|                                                       +------------------+   |

Rung 2:3
|                                                        Over                   |
|                                                        Range                  |
| +GRT---------------+                                       B3                 |
|-+GREATER THAN      +--------------------------------+----(L)---------------+-|
| |Source A      N7:0|                                |       1              | |
| |                 0|                                |                      | |
| |Source B      2047|                                |                      | |
| |                  |                                |                      | |
| +------------------+                                | +MOV---------------+ | |
|                                                     +-+MOVE              +-+ |
|                                                       |Source        2047|   |
|                                                       |                  |   |
|                                                       |Dest          N7:0|   |
|                                                       |                 0|   |
|                                                       +------------------+   |

Rung 2:4
|                                                    +PID--------------------+ |
|----------------------------------------------------+PID                    +-|
|                                                    |Control Block     N10:0| |
|                                                    |Process Variable   N7:0| |
|                                                    |Control Variable N10:29| |
|                                                    |Control Block Length 23| |
|                                                    +-----------------------+ |

Rung 2:5
The PID control variable is the input for the scale instruction.  The PID
instruction guarantees that the CV remains within the range of 16383.  The CV
is scaled to 6242–31208, the numeric range required for a 4–20 mA output signal.
|                                                    +SCL--------------------+ |
|----------------------------------------------------+SCALE                  +-|
|                                                    |Source           N10:29| |
|                                                    |                      0| |
|                                                    |Rate [/10000]     15239| |
|                                                    |                       | |
|                                                    |Offset             6242| |
|                                                    |                       | |
|                                                    |Dest              O:1.0| |
|                                                    |                       | |
|                                                    +-----------------------+ |

Rung 2:6
This rung immediately updates the analog output card driven by the PID’s CV.
|                                                    +IOM--------------------+ |
|----------------------------------------------------+IMMEDIATE OUT w MASK   +-|
|                                                    |Slot              O:1.0| |
|                                                    |Mask               FFFF| |
|                                                    |Length                1| |
|                                                    +-----------------------+ |

Rung 2:7
|                                                                               |
|------------------------------------+END+------------------------------------|
|                                                                               |
```

Chapter 6

Calibrating the Module

This appendix helps you calibrate the module's analog input channels to increase the expected accuracy from ± 21 LSB of error to ± 6 LSB. The combination of calibration program and procedure is designed to reduce offset and gain errors by:

- scaling the values read during calibration
- applying them during runtime

We present example computations and ladder logic for your reference.

Calibration Tradeoffs

Operating a calibrated module requires the addition of the calibration program for each calibrated input channel. Scanning the calibration program increases the program scan time during runtime, slowing the module's response. If the overall channel error of ± 0.510% of full scale at 77ºF is acceptable to your application, you need not calibrate. If you require a calibrated input channel, consider recalibrating every time you change the input sensor and/or the analog module.

Calibrating an Analog Input Channel

To illustrate how to calibrate an analog input channel, we present:

- an example calibration program
- a calibration procedure

This example assumes an analog output of 4-20 mA from a transducer. The corresponding decimal code that the module would write into the processor's input image table would be 409 at 4 mA and 2047 at 20 mA if the overall error of an input channel were zero. However, the overall error of ± 0.510% at 20 mA equates to ± 21 LSB of error, or a code range of 2026 to 2068. In other words, the value that the module transfers to the data table for a full scale sensor signal of 20 mA could be any value within the range of 2026 to 2068. Calibration should reduce the overall error to less than ± 6 LSB, or a code range of 2041 to 2053 for the error of the 20 mA signal.

With this full-scale sensor output:	For an *uncalibrated* channel, the corresponding output would have this range of error:	For a *calibrated* channel, the corresponding output would have this range of error:
20 mA >>	2068 >>> 2047 >>>> 2026	2053 >>> 2047 2041

Example Calibration Program

To maintain calibrated inputs for each channel, you must:

- add a calibration program for each channel to your application logic
- calibrate each channel
- enable the Convert Enable rung (rung 2:4) during runtime

The calibration program requires 3 external inputs to calibrate each channel:

- Lo captures the low calibration value (calibration procedure, step 3)
- Hi captures the high calibration value (calibration procedure, step 4)
- Cal scales the Hi and Lo values to provide the slope and offset (step 5)

The following addresses are used in the example program:
(Each channel requires its own program and separate addresses.)

Bit or Value	Address
Cal_Lo	I:1.0/0 and N10:0/0 (You set these bits in step 3.)
Cal_Hi	I:1.0/1 and N10:0/1 (You set these bits in step 4.)
Calibrate	I:1.0/2 and N10:0/2 (You set these bits in step 5.)
Convert Enable	N10:10/4 (Runtime enable)
Analog_In	I:2.0
Lo_Value	N10:1
Hi_Value	N10:2
Scale_Hi	N10:3
Scale_Lo	N10:4
Scale_Span	N10:7
Span	N10:9
Slope_x10K	N10:18
Offset	N10:21
Analog Scale	N10:22

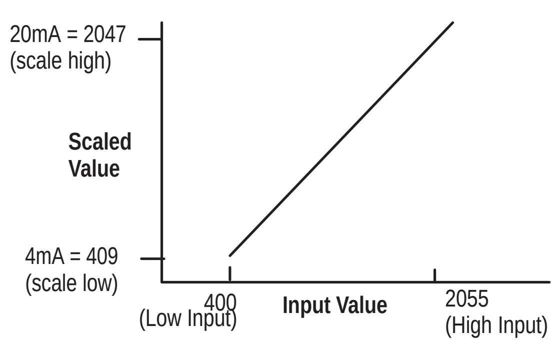
Compute values required for the calibration program as follows:

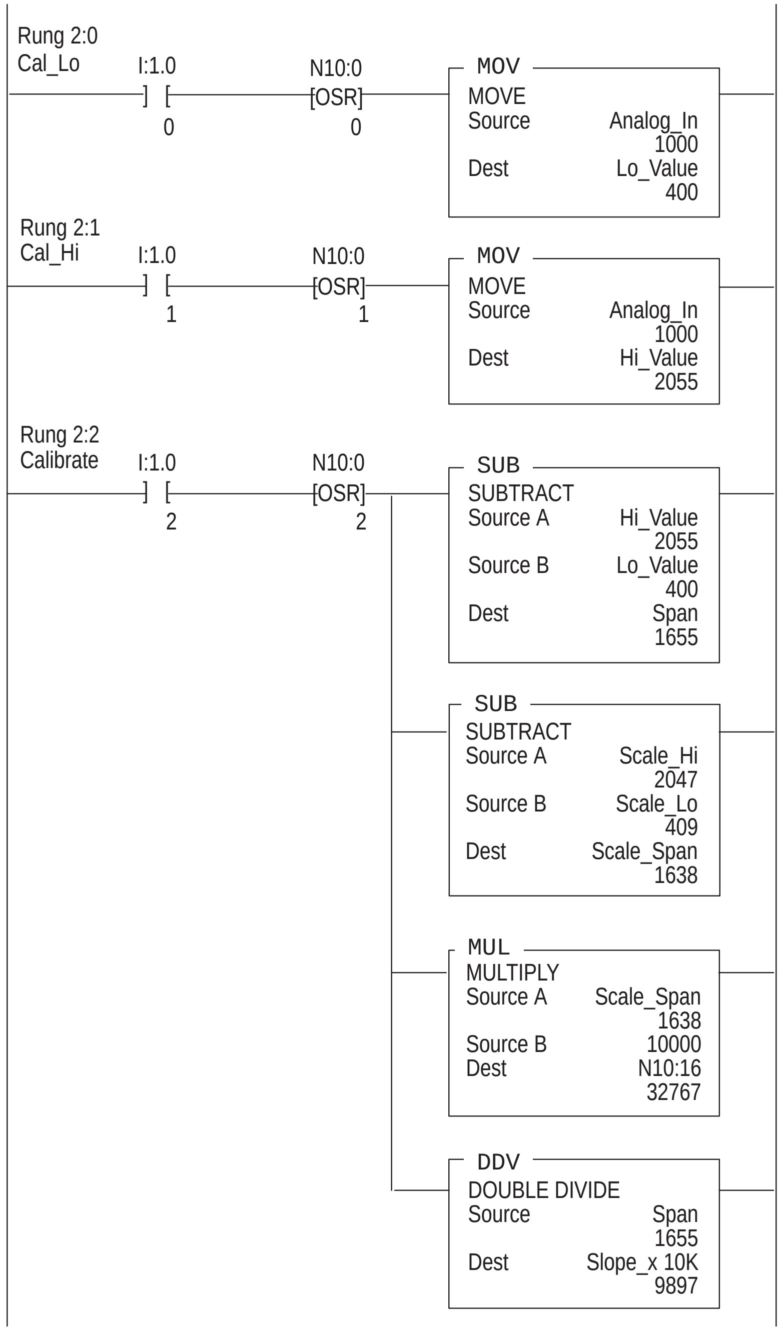
Scaled Value = (input value x slope) + offset

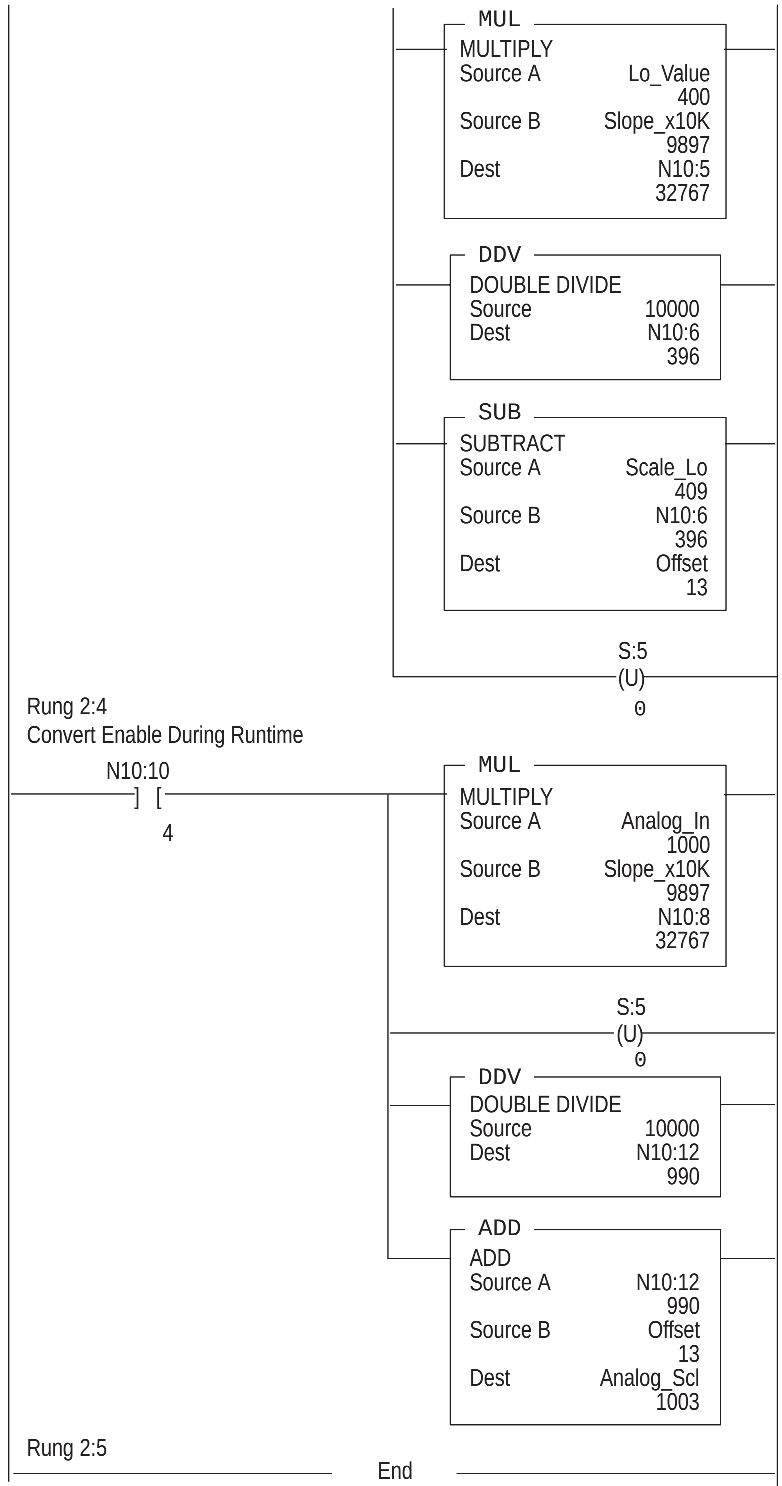
Slope = (scaled max. – scaled min.) / (input max. – input min.)
= (2047 – 409) / (2055 – 400) [1] = 1638 / 1655 = **.9897**

[1] The values of 2055 and 400 are from the calibration procedure steps 3 and 4, respectively.

Offset = Scaled min. – (input min. x slope)
= 409 – (400 x .9897) = 409 – 395.88 = 13.12




Rung 2:0
Cal_Lo
I:1.0
] [
0
N10:0
[OSR]
0
MOV
MOVE
Source Analog_In
1000
Dest Lo_Value
400
Rung 2:1
Cal_Hi
I:1.0
] [
1
N10:0
[OSR]
1
MOV
MOVE
Source Analog_In
1000
Dest Hi_Value
2055
Rung 2:2
Calibrate
I:1.0
] [
2
N10:0
[OSR]
2
SUB
SUBTRACT
Source A Hi_Value
2055
Source B Lo_Value
400
Dest Span
1655
SUB
SUBTRACT
Source A Scale_Hi
2047
Source B Scale_Lo
409
Dest Scale_Span
1638
MUL
MULTIPLY
Source A Scale_Span
1638
Source B 10000
Dest N10:16
32767
DDV
DOUBLE DIVIDE
Source Span
1655
Dest Slope_x 10K
9897


MUL
MULTIPLY
Source A Lo_Value
400
Source B Slope_x10K
9897
Dest N10:5
32767
DDV
DOUBLE DIVIDE
Source 10000
Dest N10:6
396
SUB
SUBTRACT
Source A Scale_Lo
409
Source B N10:6
396
Dest Offset
13
S:5
(U)
0
Rung 2:4
Convert Enable During Runtime
N10:10
] [
4
MUL
MULTIPLY
Source A Analog_In
1000
Source B Slope_x10K
9897
Dest N10:8
32767
S:5
(U)
0
DDV
DOUBLE DIVIDE
Source 10000
Dest N10:12
990
ADD
ADD
Source A N10:12
990
Source B Offset
13
Dest Analog_Scl
1003
Rung 2:5
End

Calibration Procedure

Recalibrate every 6 months, or as necessary.

1. Let the module warm up under power for at least 20 minutes at ambient operating temperature.
2. Determine the scaled high and low values you wish to use in your application. In this example, scaled high is 2047 (20 mA) and scaled low is 409 (4 mA).
3. Capture the Lo calibration value. To do this, place the input sensor (or input source) at the low (4 mA) position. Set the Cal Lo bit (I:1.0/0) and OSR bit (N10:0/0). Your low value must be within the analog input's conversion range. For this example, it is 400.
4. Capture the Hi calibration value. To do this, place the input sensor (or input source) at the high (20 mA) position. Set the Cal Hi bit (I:1.0/1) and OSR bit (N10:0/1). Your high value must be within the analog input's conversion range. For this example, it is 2055.
5. Energize the calibration input. To do this, set the Calibrate bit (I:1.0/2) and OSR bit (N10:0/2). This causes the SCL instruction to compute and store the slope and offset values used to perform the error correction to the analog input.

Important: To apply calibration values to the input channel during normal operation, enable rung 2.4 during runtime.

Chapter 7

Testing Module Operation

This chapter helps you test the operation of the module's I/O channels.

Testing the SLC 500 System

Testing the SLC 500 system is beyond the scope of this manual.
We mention it here only because you should test and debug at the system level before testing and debugging the module in the system.

If your module is installed in the expansion rack of a fixed system, test your SLC 500 System using procedures described in the Fixed Hardware Installation & Operation Manual (publication 1747-NI001) before testing the analog module.

If your analog module is installed in a modular system, test your SLC 500 System using procedures described in the Modular Hardware Installation & Operation Manual (publication 1747-6.2) before testing the analog module.

Testing the Module

Once you have tested your SLC 500 system, follow this outline to test the module at start up. We describe each or the steps in detail.

1. Inspect module switches and wiring.

2. Disconnect analog process control devices.

3. Power up the I/O rack.

4. Test analog inputs.

5. Test analog outputs.

1. Inspect Module Switches and Wiring

Inspect the module as follows before installing it. Make sure that:

a. input configuration switches 1 and 2 are set correctly

b. wiring connections are OK and no wires are missing or broken

c. terminal connections are tight to secure the wires

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

---

d. cable shields are properly grounded

ATTENTION: Do not attempt to ground the cable at the module's terminal block. It does not connect to earth ground. Ground the cable at one end only, as described in chapter 2.

e. the module's terminal block is securely connected

f. you installed the module in its addressed I/O rack slot

2. Disconnect Analog Process Control Devices

During the following test procedures, the you will operate the processor in Run mode. As a safety precaution, make sure that analog process control devices are inoperative. These devices include:

- proportional valves
- proportional drives
- servo amplifiers
- other analog signal amplifiers that drive analog output devices

Where possible, leave the module connected to the output device to serve as the output load, but inhibit its affect on controlling the process. As an alternative, substitute a passive load for the active device.

ATTENTION: Process operation during system checkout can be hazardous to personnel. During checkout procedures, disconnect, inhibit, or substitute a passive load for all devices which, when energized, might cause the process to operate.

3. Power Up the I/O Rack

Apply power to the fixed or modular system. The module's LED should be illuminated (red), indicating that the module is receiving power.
If not, troubleshoot the non–illuminated LED. Check the following

- The SLC 500 system is not receiving power from its power supply. For an SLC processor in the fixed system, check the processor's POWER LED. For the modular system, check the power supply LED. If the LED is not illuminated, refer to the Installation & Operation Manual or the system.
- System power is not being received by the remainder of the SLC 500 system. Test this by attempting to go online with the programming device.

- The module's slot in the I/O rack is not operational. Remove power from the SLC 500 system, move the module to another slot, and restore power. Replace the I/O rack if power distribution is faulty.
- The module is defective.

4. Test Analog Inputs

Before testing the module's input channels, the SLC 500 system must be installed and tested according to the SLC 500 Installation & Operation Manual (publication 1747-6.2 or -NI001). The processor must be connected to a programming device, properly configured, and must have no rungs in its ladder program. The module's LED must also be illuminated.

ATTENTION: Do not attempt to test the module's input channels unless its process control output devices have been disconnected, inhibited, or replaced by a passive load.

If your input sensors can be manually varied over their normal operating range, use them to test the input channels. If not, use a replacement voltage or current source after disconnecting the sensor.

Important: If a current source is not available to test a current input channel, carefully apply a substitute input voltage instead. Determine the substitute input voltage as follows:

Voltage Input (V) = Current Input (mA) x 0.25

For example, substitute input voltages for 1 mA, 5 mA, and 20 mA inputs would be 0.25, 1.25, and 5.0 volts, respectively. Do not exceed 5 volts.

In normal operation, a voltage source should not be connected to an analog input channel in the current mode.

a. Determine the limits of the sensor's signal range for the channel. For example, if the sensor has an output range of 1 to 5 mA, the lower limit is 1 mA and the upper limit is 5 mA.

b. Compute the decimal value that should appear in the processor's input image table for the sensor's lower and upper signal limits at the input channel.

   For example, limits of 1 mA and 5 mA would have typical decimal values of 407 and 2047, respectively. If necessary, refer to the section, Converting Analog Input Data, in chapter 4.

c. With the programming device on–line, select the processor's Test- Continuous scan mode. This provides a safer testing mode because outputs are not energized.

d. Display the data in File 2 (Input Image Table). Select the Data Monitor mode of your programming device when viewing I/O point I:1.0.

e. Change the radix of the display to decimal.

f. If the sensor is connected, set it to its lower limit.
If the sensor was disconnected from the module's input channel, attach the replacement voltage or current source and set the source to the lower limit.

g. Locate the channel's signal in the input image table. The signal should be approximately equal to the lower limit computed in step b.

The value of the input image word is affected by the accuracy of the module and sensor. Any error should be within the sum of their tolerances.

h. If the sensor is connected, set it to the upper limit.
If the sensor was disconnected from the module's input channel, set the replacement voltage or current source to the upper limit.

i. Repeat step f, this time for the upper limit.

j. Repeat steps a through i for the other analog input channel.

If either of the analog input channels do not pass this start–up procedure, check for the following potential causes:

- The analog sensor (voltage or current source) is not operating properly.
- The processor is not in the Test/Continuous scan mode.
- The terminal block is not secured on the module.
- The terminal block is not wired properly or wires are broken.

5. Test Analog Outputs

Before testing the module's output channels, the SLC 500 system must be installed and tested according to the SLC 500 Installation & Operation Manual (publication 1747-6.2 or -NI001). The processor must be connected to a programming device, properly configured, and must have no rungs in its ladder program. The module's LED must also be illuminated.

ATTENTION: Do not attempt to test the module's output channels unless its process control output devices have been disconnected, inhibited, or replaced by a passive load.

If the output device controls a potentially dangerous operation or a prime mover, use a voltmeter to test voltage outputs or an ammeter to test current outputs. Note that these meters have some inherent error of their own.

If using a meter, disconnect the output device and/or use a substitute load.

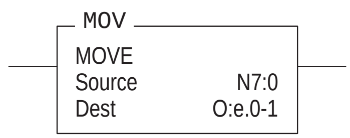
a. Determine the lower and upper limits of the module's output channel. For example, if connected to a signal amplifier with an input range of 1 to 5 volts, the signal limits are 1 volt (lower) and 5 volts (upper).

b. Compute the decimal value that should appear in the processor's output image table for the channels lower and upper signal limits.

   For example, limits of 1 and 5 volts would have decimal values of 3277 and 16384, respectively. If you need help, refer to the section, Converting Analog Output Data, in chapter 4.

c. With the programming device on–line, select Program mode.

d. Create and save the test rung shown below.



"e" is the module's I/O rack slot number
"0-1" is the number of the module's output channel being tested

e. Download the test rung to the processor and select RUN mode.

f. Display the data in address N7:0.

g. Enter lower limit in N7:0.
   For example, if the lower limit is 1 volt, enter 3277 into N7:0.

h. If the output device is connected to the output channel, the device should assume its lower limit condition. Check that it did.

   If the output device is disconnected, read the replacement meter. Do not overlook module and meter errors.

i. Enter the upper limit in N7:0.
   For example, if the upper limit is 5 volts, enter 16384 into N7:0

j. Repeat step g, this time for the upper limit.

k. Repeat steps a through j for the other output channel.

If either output channel does not pass this start–up procedure, check that the:

- actuator or test meter is operating properly
- processor is in RUN mode
- terminal block is secured to the module
- terminal block is wired properly or wires are not broken

Chapter 8

Maintenance and Safety

This chapter provides preventive maintenance information and safety considerations when troubleshooting your SLC 500 system.

Preventive Maintenance

The printed circuit boards of the analog modules must be protected from dirt, oil, moisture and other airborne contaminants. To protect these boards, the SLC 500 system must be installed in an enclosure suitable for the environment. The interior of the enclosure should be kept clean and the enclosure door should be kept closed whenever possible.

Regularly inspect your terminal connections for tightness. Loose connections may cause improper functioning of the SLC 500 system or damage the components of the system.

ATTENTION: To ensure personal safety and to guard against damaging equipment, inspect connections with incoming power turned OFF.

The National Fire Protection Association (NFPA) recommends maintenance procedures for electrical equipment. Refer to article 70B of the NFPA for general requirements regarding safety related work practices.

Safety Considerations When Troubleshooting

Safety considerations are an important element of proper troubleshooting procedures. Actively thinking about the safety of yourself and others, as well as the condition of your equipment, is of primary importance. Refer to the Fixed or Modular I/O Hardware Installation and Operation manual for additional information on troubleshooting.

Follow these suggestions when troubleshooting your SLC 500 system.

Indicator Lights – When the red LED on the analog module is illuminated it indicates that 24 V dc power is applied to the module.

Activating Devices When Troubleshooting – When troubleshooting, never reach into the machine to actuate a device. Unexpected machine motion could occur. Use a wooden stick.

Stand Clear of Machine – When troubleshooting any SLC 500 system problem, have all personnel remain clear of the machine. The problem could be intermittent, and sudden unexpected machine motion could occur. Have someone ready to operate an emergency stop switch in case it becomes necessary to shut off power to the machine.

When troubleshooting, pay careful attention to this general warning:

ATTENTION: Never reach into a machine to actuate a switch since unexpected machine motion can occur and cause injury.

Remove all electrical power at the main power disconnect switch before checking electrical connections or inputs/outputs that cause process actuation or machine motion.

Program Alteration – There are several causes of alteration to the user program, including extreme environmental conditions, Electromagnetic Interference (EMI), improper grounding, improper wiring, and unauthorized tampering. If you suspect the program has been altered, check it against a previously saved program on an EEPROM or UVPROM memory module.

Safety Circuits – Circuits installed on the machine for safety reasons, like over-travel limit switches, stop pushbuttons, and interlocks, should always be hard–wired to the master control relay. These devices must be wired in series so that when any one device opens, the master control relay is de–energized thereby removing power to the machine. Never alter these circuits to defeat their function. Serious injury or machine damage could result.

Appendix **A**

Module Specifications

General Description

The 1746-FIO4I and -FIO4V fast analog I/O modules provide two input and two output channels. Input channels are the same for both types of modules: you select either current or voltage operation for each channel. The 1746–FIO4I module contains two current-output channels, while the 1746–FIO4V module contains two voltage-output channels.

Specifications

Specifications for the fast analog I/O modules include:

- General specifications
- General input specifications
- Voltage input specifications
- Current-loop input specifications
- Current output specifications for the 1746-FIO4I
- Voltage output specifications for the 1746-FIO4V

General Specifications

Catalog 1746-	Input Channels per Module	Output Channels per Module	Backplane Current 5V	Backplane Current 24V	ID Code
FIO4I	2 differential, voltage or current, selectable per channel	2 current outputs, not individually isolated	55 mA	150 mA	3224
FIO4V	same as FIO4I	2 voltage outputs, not individually isolated	55 mA	120 mA	3218

Description	Specification
Cable	shielded, Belden #8761 (recommended)
Wire Size	#14 AWG (maximum)
Terminal Block	removable
Installation	single slot in the 1746 I/O Rack
Calibration	customer calibration program and procedure in Chapter 6
Noise Immunity	NEMA standard ICS 2–230
Environmental Conditions	
Operating Temperature	0° to +60° C (+32° to +140° F)
Storage Temperature	–40° to +85° C (–40° to +185° F)
Relative Humidity	5 to 95% (non–condensing)

General Input Specifications

Description	Specification
Converter Resolution	12 bits
Converter Type	successive approximation
Track and Hold Time To Acquire the Analog Signal Before Conversion	1.5 µs (nominal)
Signal Convert from Hold	6.0 µsec (nominal)
Conversion Time (sum of above two specs.)	7.5 µsec every 512 µsec (nominal)
Non–linearity	±0.073% of full scale (maximum)
Location of LSB in I/O image word	0000 0000 0000 0001
Image Format (HEX)	0FFF
Common Mode Voltage Range	0 to +20 volts (maximum)
Common Mode Rejection at 60 Hz	50 dB (minimum with 1K ohm imbalance)
Channel Bandwidth	7.0 kHz (minimum @ 3 dB point)
Module Throughput Delay	1.10 ms (maximum [1]) 512 µsec (typical)
Step Response (5% to 95%)	100 µsec
Impedance to ANL COM	500K ohms
Impedance Channel-to-channel	1M ohms
Field Wiring to Backplane Isolation	500V dc

[1] Worst case throughput occurs when the module just misses seeing an event occur. For additional information, refer to Input Filtering in chapter 3.

Voltage Input Specifications

Description	Specification
Input Operating Range	0 to +10V dc (maximum)
Input Impedance	1M ohms (nominal)
Resolution	2.4414 mV per LSB (nominal)
Voltage Input Coding (0 to +10VDC – 1 LSB)	0 to 4095 counts
Overall Accuracy at +25° C (77° F)	±0.440% of full scale
Overall Accuracy at +60° C (140° F)	±0.750% of full scale
Overall Accuracy Drift	±88 ppm/° C (maximum)
Gain Error at +25° C (77° F)	±0.323% of full scale
Gain Error at 0° to +60° C (32° to 140° F)	±0.530% of full scale
Gain Error Drift	±79 ppm/° C (maximum)
Offset Error at 0° to +60° C (32° to 140° F)	±4 LSB (maximum)
Offset Error at +25° C (77° F)	±2 LSB (typical)
Offset Error Drift	±0.14 LSB/° C (maximum [1])
Overvoltage Protection (IN+ to IN–)	220V dc or ac RMS, continuously

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

Current–loop Input Specifications

Description	Specification
Input Operating Range	0 to 20 mA (nominal) 0 to 30 mA (maximum)
Input Voltage	±7.5V dc or ac RMS (maximum)
Current Input Coding Range (0 to 20 mA)	0 to 2047 counts
Input Impedance	250 ohms (nominal)
Resolution	9.7656 µA per bit
Overall Accuracy at +25° C (77° F)	±0.510% of full scale
Overall Accuracy at +60° C (140° F)	±0.850% of full scale
Overall Accuracy Drift	±98 ppm/° C of full scale (maximum)
Gain Error at +25° C (77° F)	±0.400% of full scale
Gain Error at 0° to +60° C (32° to 140° F)	±0.707% of full scale
Gain Error Drift	±89 ppm/° C (maximum)
Offset Error at 0° to +60° C (32° to 140° F)	±4 LSB
Offset Error at +25° C (77° F)	±2 LSB (typical)
Offset Error Drift	±0.14 LSB/° C (maximum [1])
Overvoltage Protection	7.5V ac RMS (maximum)

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

Current Output Specifications for FIO4I

Description	Specification
Converter Resolution	14 bit
Location of LSB in I/O Image Word	0000 0000 0000 01XX
Non–linearity	0.05% of full scale (maximum)
Conversion Method	R–2R ladder
Step Response	2.5 ms (at 95%)
Load Range	0 to 500 ohms
Load Reactance	100 µH (maximum)
Current Output Coding (0 to +21mA – 1 LSB)	0 to +32,764
Output Range	0 to +20 mA –1 LSB (normal)
Overrange Capability	5% (0 to 21 mA – 1 LSB)
Resolution	2.56348 µA per LSB
Full Scale	21 mA
Overall Accuracy at +25° C (77° F)	±0.298% of full scale
Overall Accuracy at 0° to +60° C (32° to 140° F)	±0.541% of full scale
Overall Accuracy Drift	±70 ppm/° C of full scale (maximum)
Gain Error at +25° C (77° F)	±0.298% of full scale
Gain Error at 0° to +60° C (32° to 140° F)	±0.516% of full scale
Gain Error Drift	±62 ppm/° C (maximum)
Offset Error at +25° C (77° F)	±10 LSB (typical)
Offset Error at 0° to +60° C (32° to 140° F)	±12 LSB
Offset Error Drift	±0.06 LSB/° C (maximum)

Voltage Output Specifications for FIO4V

Description	Specification
Converter Resolution	14 bit
Location of LSB in I/O image word	0000 0000 0000 01XX
Non–linearity	0.05%of full scale
Conversion Method	R–2R ladder
Step Response (to 95%)	2.5 ms (normal)
Load Range	1K to ∞ Ohms
Load Current	10 mA (maximum)
Load Reactance	1µF (maximum)
Voltage Output Coding (–10 to +10VDC – 1 LSB)	–32,768 to +32,764
Output Range	–10 to +10V – 1 LSB (normal)
Resolution	1.22070 mV per LSB
Full Scale	10V dc
Overall Accuracy at +25° C (77° F)	±0.208% of full scale
Overall Accuracy at 0° to +60° C (32° to 140° F)	±0.384% of full scale
Overall Accuracy Drift	±54 ppm/° C of full scale (maximum)
Gain Error at +25° C (77° F)	±0.208% of full scale
Gain Error at 0° to +60° C (32° to 140° F)	±0.374% of full scale
Gain Error Drift	±47 ppm/° C (maximum)
Offset Error at +25° C (77° F)	±9 LSB (typical)
Offset Error at 0° to +60° C (32° to 140° F)	±11 LSB
Offset Error Drift	±0.05 LSB/° C (maximum)

2's-complement Binary Numbers

Using 2's-complement Binary Numbers

The SLC 500 processor stores data as 16–bit binary numbers. The processor uses 2's-complement binary format when making mathematical computations and when storing analog values in the I/O image table.

As indicated in the figure below, the equivalent decimal value of the 2's-complement binary number is the *sum* of corresponding position values. The corresponding position value is equal to 2 raised to the power designated by the position, beginning at the right with 2^0 and ending at the left with 2^{15}. The bit value in each position can be 0 or 1, where 0 excludes the corresponding position value from the sum and 1 includes it.

Positive Decimal Values

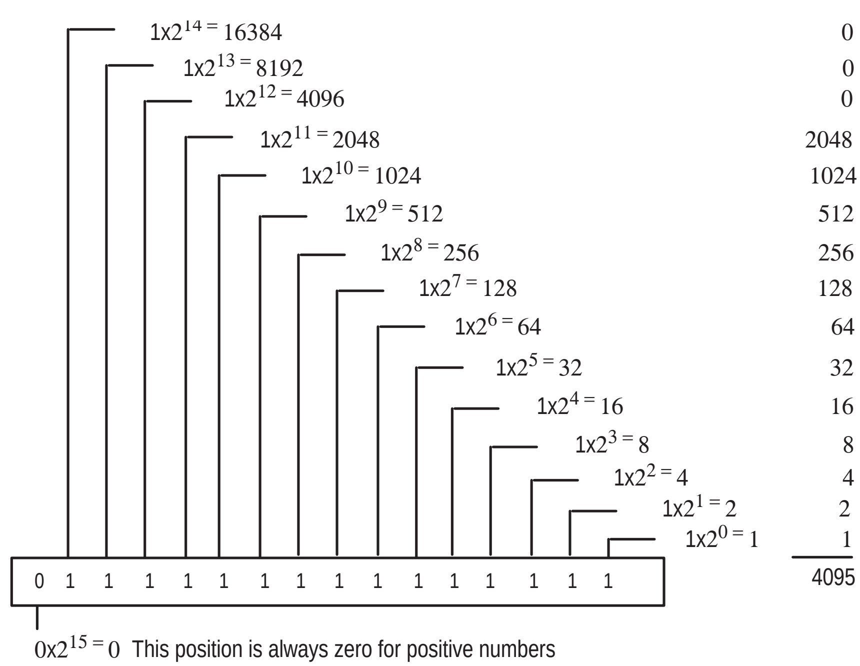
The far left position is always 0 for positive values. Binary notation and 2's-complement binary notation are identical for positive values. This format limits the maximum positive value to 32767 when all positions are 1 except for the far left position (see figure below). Study these examples:

0000 1001 0000 1110 = $2^{11} + 2^8 + 2^3 + 2^2 + 2^1$

= 2048 + 256 + 8 + 4+2 = 2318

0000 0011 0010 1000 = $2^9 + 2^8 + 2^5 + 2^3$

= 512 + 256 + 32 + 8 = 808



Negative Decimal Values

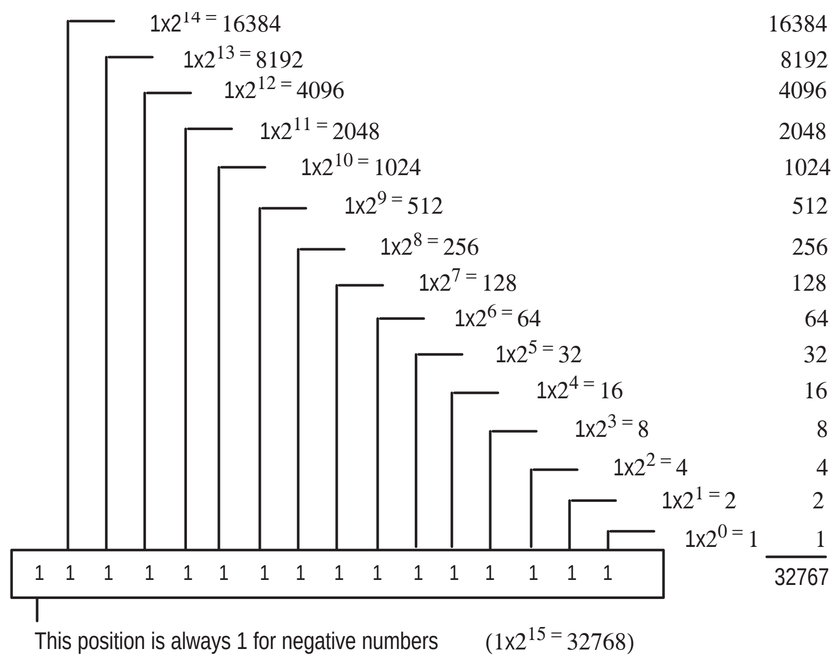
The far left position is always 1 for negative values. The equivalent decimal value of a negative 2’s-complement binary number is obtained by subtracting 32768 from the sum of the other position values. In the figure below, all positions are 1 and the value is 32767 – 32768 = –1. Study this example:

1111 1000 0010 0011 =

$(2^{14}+2^{13}+2^{12}+2^{11}+2^{5}+2^{1}+2^{0}) - 2^{15} =$

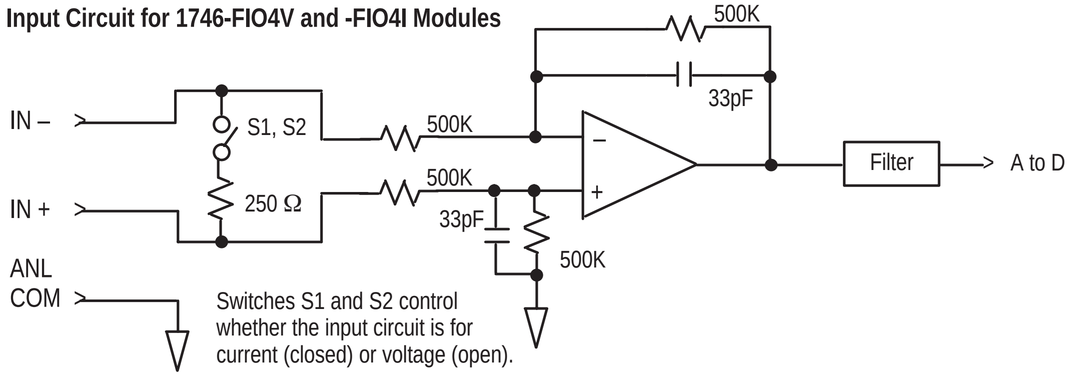
(16384+8192+4096+2048+32+2+1) – 32768 =

30755 – 32768 = –2013.

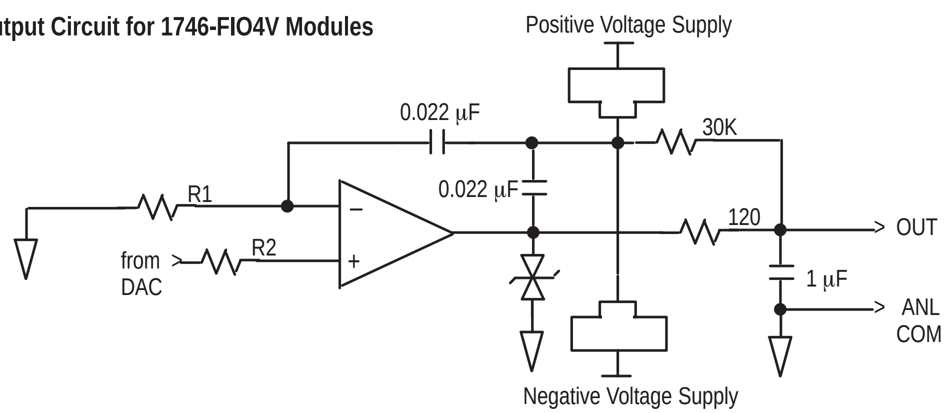


Module Input and Output Circuits

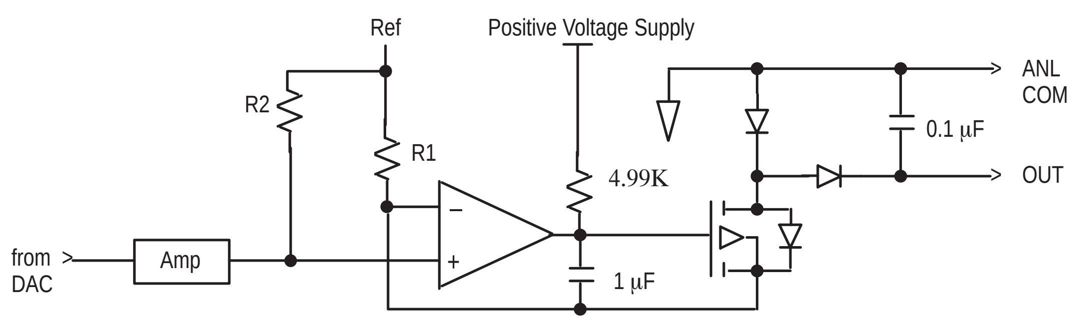
Input Circuit for 1746-FIO4V and -FIO4I Modules



Voltage Output Circuit for 1746-FIO4V Modules



Current Output Circuit for 1746-FIO4I Modules



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