Westinghouse

numa-logic

ANALOG-to-DIGITAL INPUT MODULE

Catalog No. NL-740

PERFORMANCE DATA

Circuits per Module	2 uni-polar (standard) or 1 bi-polar (optional)
I/O Rack Positions	2
Input Ranges	• 0 to 5 VDC • 0 to 10 VDC • 1 to 5 VDC (4 to 20 mA or 10 to 50 mA) ① • 0 to 100 mV • 0 to 500 mV • 0 to 1 V
Input Impedance	10 megohms
Resolution	1 part in 4096
Output to Processor	12 bits (binary value)
A/D Conversion	Dual-slope integration type (30 conversions/sec rate)
Thruput	33 ms plus Processor scan
Absolute Accuracy	±0.1% of span ②
Common Mode Rejection Ratio RTI	120 db at DC, AC line and harmonic frequencies
Normal Mode Rejection Ratio RTI	60 db at AC line and harmonics
Common Mode Voltage (max.)	100 Vrms from either analog input to ground
Gain, Offset Temp. Coefficient	±0.1% of full scale
Power Requirements	0 units, Logic Power 0 units, Output Power +12 VDC (±0.5 V), 400 mA +5.8 VDC (±0.1 V), 400 mA
Input Protection	Withstands 120 VAC continuous
Opto Isolation	2500 V (for Processor)
Temperature Rating	0° to 60°C
Humidity Rating	0 to 97% non-condensing
Keying Slots NL-740A thru F	Between pins: 9 and 11 21 and 23

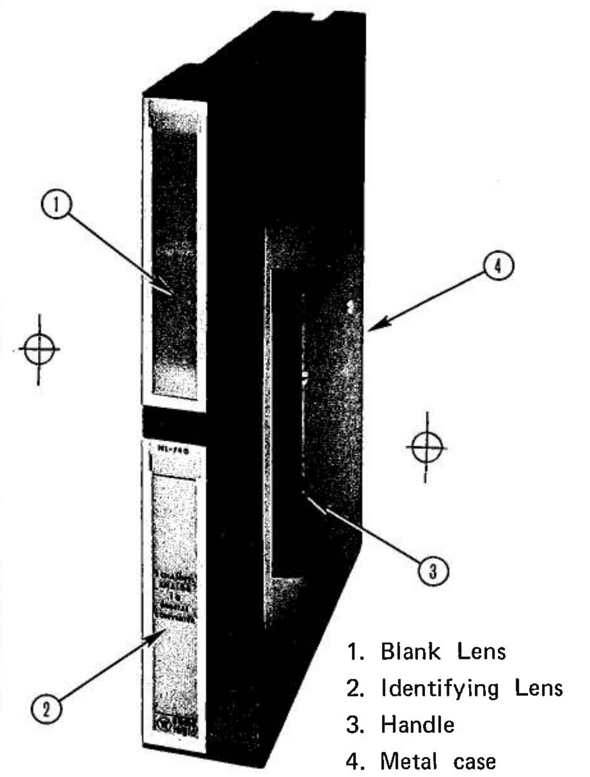

Figure 1 — Analog-to-Digital Input Module

INTRODUCTION

The function of the Analog-to-Digital (A/D) Input Module is to convert 2 uni-polar analog input voltages into binary numbers which are transferred into separate input registers in the Processor during the I/O scan. Two electrically isolated analog inputs, referred to here as "channels," are each capable of converting voltage levels into binary numbers from 0 to 4095. The Module performs an "offset measurement" every 500 conversions (16.67 seconds) and stores the resultant value in order to automatically provide "zero offset compensation." This

① With appropriate resistors wired across the analog input

② Includes temperature, gain and offset errors function guards against the effects of temperature changes and imbalances due to component aging; it also produces superior long-term accuracy.

Addressing of the separate channels is determined by settings on 2 thumbwheel switches located on the Module and a switch assembly on the I/O Rack.

Six versions of the Catalog No. NL-740 Module are available. They are distinguished by the analog input voltage range each accepts:

- NL-740A – 0 thru 5 V
- NL-740B – 0 thru 10 V
- NL-740C – 1 thru 5 V (4 thru 20 mA, or 5 thru 50 mA)
- NL-740D – 0 thru 1 V
- NL-740E – 0 thru 500 mV
- NL-740F – 0 thru 100 mV

The Module can accept an analog current input if user-supplied resistors are added to convert the current input to a voltage. (See Application Note 4.)

In addition, the Module automatically checks for a number of malfunctions, and, upon detecting one, outputs a signal that sets to Logic "1" bit 16 of the input registers associated with each channel of the Module. This can be detected by the program and appropriate action can be taken.

The Module is a double-height, double-width type. Field wiring to it is through terminals on the I/O Rack. Each channel uses 3 terminals:

- + Analog In
- - Analog In
- Shield

For proper operation of the Module, 2 external power supplies are required. (See Application Note 2.)

The Module includes 2 Lenses; the upper is blank, the lower identifies the Module.

Also supplied with the Module is a Terminal Identification Strip, which is to be filled in with wire numbers and applied to the I/O Rack next to the terminals. (See Figure 2.)

INSTALLATION

Proper Sequence – This installation procedure is divided into two distinct parts. First, connect field wiring to the I/O Rack but **do not** install the Module. Second, after AC power can **safely** be applied to the whole system, voltage measurements must be taken **before** installing the A/D Input Module(s). (This phase can be part of the start-up procedures.)

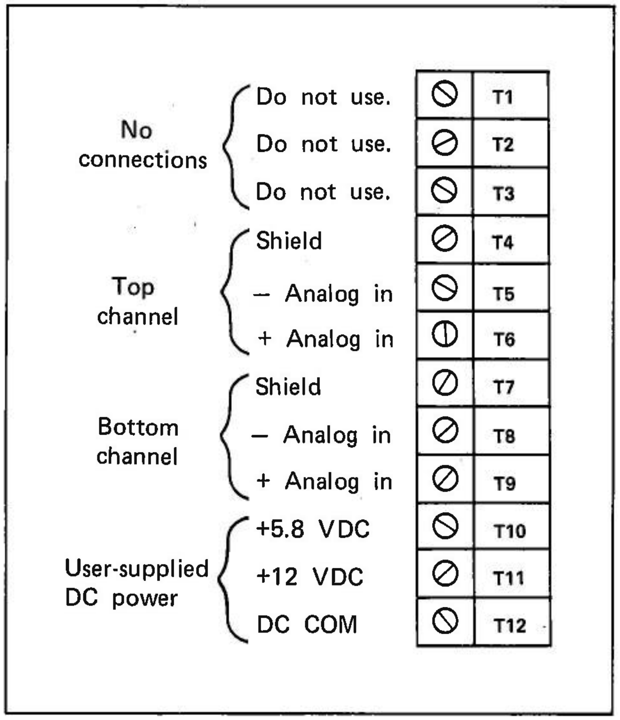

Figure 2 – Terminal Identification

CAUTION

Install the A/D Input Modules **only** after AC line power can be **safely** applied to the entire system and after the electrical measurements, described here, have been made. Equipment damage can result if this sequence is not followed.

CAUTION

Gain and offset adjustments for this Module are not user accessible and should not be attempted. Attempting to modify the factory settings can cause damage and/or result in improper Module operation.

Wiring – Refer to the system drawings and determine the exact I/O Rack Positions in which the Module will be placed. (See Figure 5 for an explanation of "position.") Use a screwdriver to remove the terminal block adjacent to the top half of the Module to allow for its width. (See Figure 3.) Field wiring connects only to the lower terminals. Follow system wiring diagrams and carefully observe the type of conductor specified. A typical connection diagram is shown in Figure 4.

CAUTION

Wire the external power supplies with the DC COM isolated from chassis ground. Follow Figure 4. Failure to do so will result in improper operation and/or equipment damage.

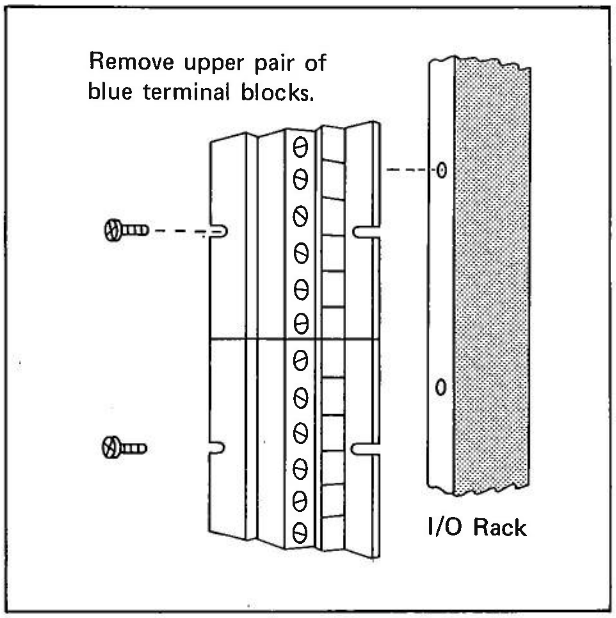

Figure 3 — Terminal Block Removal

Terminals T4 and T7 both require a user-provided earth ground connection. Use a wire no larger in size than AWG No. 14 at the I/O Rack terminals. Connect to the enclosure **only** if it is certain that there is an earth ground connection provided on that enclosure.

Follow system drawings and follow Application Note 1.

Physical Placement — Only after AC line power can be safely applied to the entire application should preparations be made to install the A/D Input Module(s) in the I/O Rack. It is a simple process, but certain electrical measurements must be made first. A voltmeter is required.

Step 1 — Apply AC power to the entire application, and verify that the voltage between the +5.8 VDC terminal (T10) and the DC COM terminal (T12) is +5.8 VDC (±0.1 V). Measure at all other I/O Rack terminals used for A/D Input Modules.

Step 2 — If necessary, adjust the external power supply's output to the required voltage.

Step 3 — Verify that the voltage between the +12 VDC terminal (T11) and the DC COM terminal (T12) is +12 VDC (±0.5 V). Measure at all other I/O Rack terminals used for A/D Input Modules.

Step 4 — If necessary, adjust the external power supply's output to the required voltage.

Step 5 — Remove AC power from the application.

Step 6 — Refer to system drawings and determine which I/O Rack and which Position in the Rack the Module is to be placed. (Although a Module can be placed in either the upper 2 Positions or the lower 2 Positions, it may

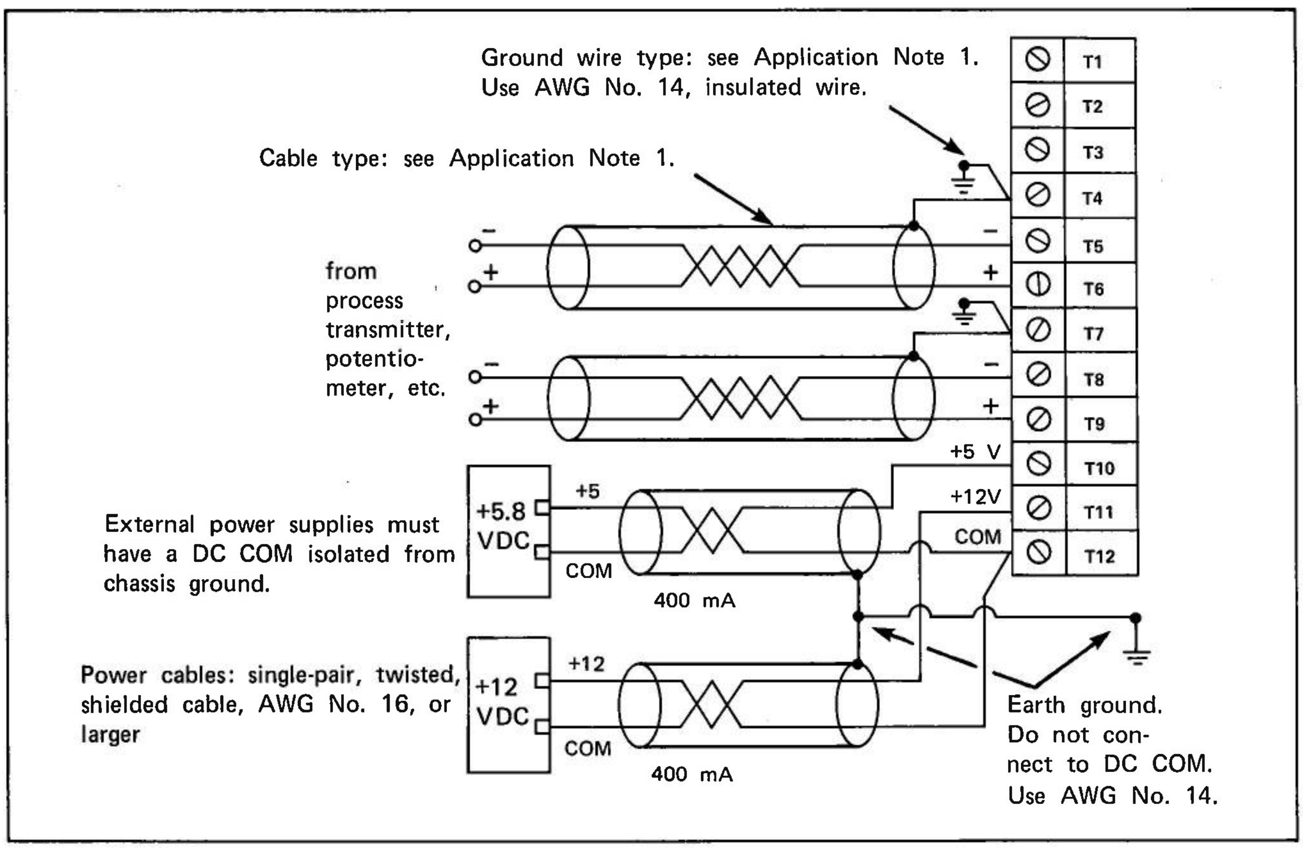

Figure 4 — Connection Diagram (typical)

not straddle Positions B and C. See Figure 5.) It is important that it be placed according to the user program Reference Number scheme.

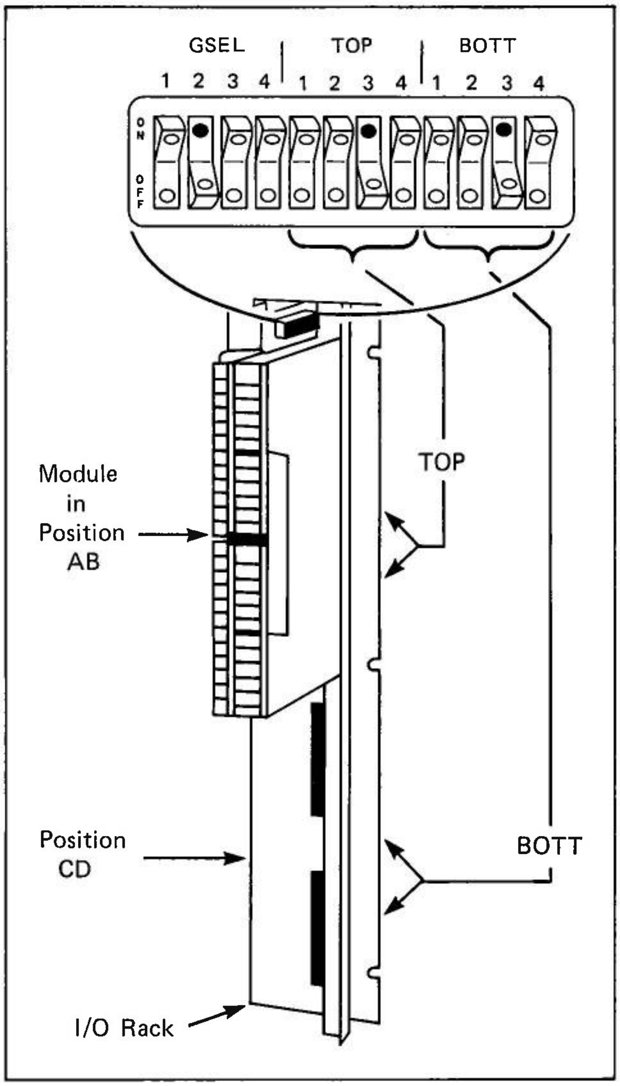

Figure 5 — Rack Switch Location

Step 7 — Move the Locking Bar on the I/O Rack's built-in terminal block to the left in order to uncover the guide slots on the block. (See Figure 6.)

Step 8 — Align both of the Module's guide pins with corresponding slots on the I/O Rack. Gently press the Module into the edge connector on the Rack. Make sure the edge pins on the Module align and mate with the Rack connector.

Step 9 — When the Module is properly seated, snap the Rack's Locking Bar over the Module's guide pins in order to hold it in place. (Note: thumbwheel switches on the Module will be set in subsequent steps.)

Step 10 — Write the wire number, or other identifying information, on the Terminal Identification Strip for subsequent use. Wiring practices to the terminals on the I/O Rack are described in the PC-900 and PC-700 Application Manuals.

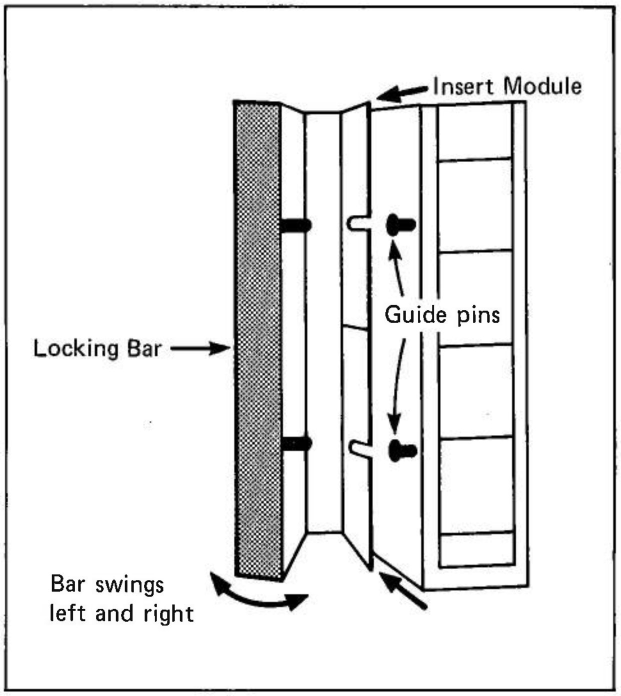

Figure 6 — Guide Slots

Switch Settings — In order to complete installation of the A/D Input Module, it is necessary to physically set individual rocker switches on the I/O Rack. Their combined function is to electrically identify each terminal in the Rack with a Reference Number required for programming. This explanation is detailed only to the level required by the installation team. (For further details, see the PC-700 and PC-900 Applications Manuals and, also, Instruction Leaflet 15718.)

Step 1 — Locate the first-used A/D Input Module on the system drawings and on the I/O Rack. This may be anywhere in the layout and will probably be grouped together with other Input Modules of the same type.

Step 2 — Identify the Reference Number for the first input terminal on **that** Module. It will be a number like IR0001.

Step 3 — At the top right-hand side of **that** I/O Rack, locate the Rack Switch assembly. (See Figure 5.) Note that it is divided into 3 groups of 4 rocker switches each. Locate those that make up the GSEL area.

It is necessary to set 1 of the 4 switches to ON according to the specific Reference Number. Relate the Number to Table A for the first Module and for all other Input Modules of this type in subsequent I/O Racks.

Step 4 — As indicated on Table A's right column, set the proper switch to the ON position.

Table A

RACK SWITCH GSEL SETTING

If the Reference Number is:	Press ON GSEL Switch:
IR0001 thru 0008	1
IR0009 thru 0016	2
IR0017 thru 0024	3
IR0025 thru 0032	4

Step 5 — Set the remaining 3 switches in GSEL to the OFF position. (The 4 switches may be thought of as a type of selector switch.)

Step 6 — Set the remaining 8 rocker switches in the TOP and BOTT areas to the OFF position.

Step 7 — Two thumbwheel switches are located near the rear edge of the Module. (See Figure 7.) Both of these must be set to a specific digit in relation to the Reference Numbers assigned to the Module's 2 channels. Read Application Note 11 and refer to Table B. Also use the list described earlier in this publication at "Switch Settings."

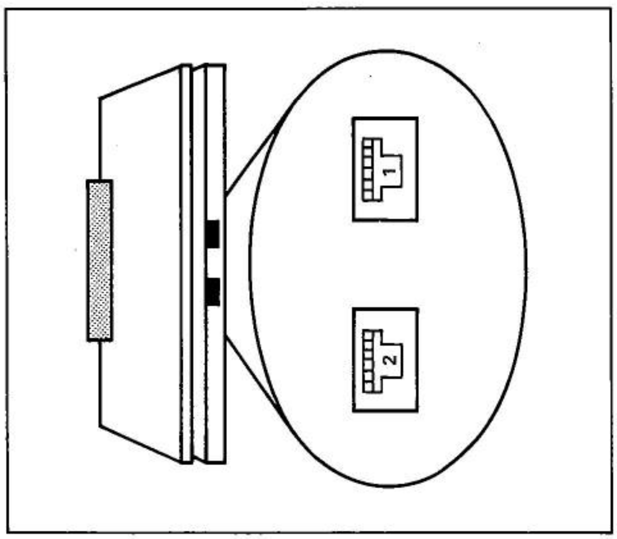

Figure 7 — Thumbwheel Switch Location

Example: the top channel is IR0017 and the bottom channel is IR0018. Answer: set the top thumbwheel to 1, and the bottom thumbwheel to 2.

Step 8 — As indicated in Table B, set the thumbwheels to the proper digits.

Step 9 — Apply AC power to the application and again measure the voltage at the same terminals noted in Steps 1 and 3 at Physical Placement, above. Measure at all I/O Rack Positions used for A/D Input Modules. Under these load conditions the level should be as specified there.

Step 10 — If necessary, readjust the power supply's output to the required voltage.

Step 11 — As an aid to future troubleshooting, mark the rocker and thumbwheel switch settings on a piece of tape and place it near the assembly.

Table B

THUMBWHEEL SETTINGS ①

If the Reference Number is:	Turn thumbwheel to this digit:
IR0001, 0009, 0017, 0025	1
IR0002, 0010, 0018, 0026	2
IR0003, 0011, 0019, 0027	3
IR0004, 0012, 0020, 0028	4
IR0005, 0013, 0021, 0029	5
IR0006, 0014, 0022, 0030	6
IR0007, 0015, 0023, 0031	7
IR0008, 0016, 0024, 0032	8

① Do not use 0 or 9.

APPLICATION NOTES

1. In order to minimize the effects of electrical noise, all field wiring must conform to the following guidelines:

- Use single-pair, twisted, shielded cable, AWG No. 22, or larger conductors, for each analog input channel.
- Use single-pair, twisted, shielded cable, AWG No. 16, or larger conductors, for each external power supply.
- Keep analog cable runs as short as possible, and route them away from AC conductors as much as possible.
- Maintain a minimum spacing of 12 in. (30.5 cm) from inductive devices such as isolation transformers, motors and starters.
- Connect all cable shields to earth ground **only** at the Module end in order to prevent ground loops. (A tie-off terminal is provided, but an additional wire must be run to an earth ground connection from this terminal (T4 and T7).

2. Each Module has a current requirement of 0.4 amperes from both a +5.8 and a +12 VDC user-provided external power supply. Westinghouse offers the following +5.8 VDC (±0.1%):

- NLPS-315, rated at 1.5 amperes
- NLPS-330, rated at 3.0 amperes
- NLPS-360, rated at 6.0 amperes

Also offered is a +12 VDC (±0.5%) power supply:

- NLDS-500, rated at 0.8 amperes

Choice can be made according to total current requirements. Equivalent types may be used.

3. Both external power supplies should be powered by the same AC line that powers the Processor. The common side of both external supplies must be connected to the Module's COM terminal (T12). See Figure 4.

CAUTION

Do not connect the external power supplies's common conductors to chassis ground. This practice results in a system malfunction and/or possible hardware damage.

4. It is possible to use an A/D channel as an analog current, but an external resistor must be added. Select the correct resistance value from Table C. Install it across T5 and T6 or T8 and T9 as shown in Figure 8. All resistors should be 0.1%, 1/2 watt precision types with a low-temperature coefficient (less than ±20 ppm).

5. It is possible to wire the top and bottom channels to form a single bi-polar analog input. To do so, connect both channels to the same analog voltage input source with their polarities reversed. In this way one channel handles the 0 to +10 VDC; the other handles the 0 to -10 VDC. (See Figure 9.)

It is also necessary to install jumpers on the I/O Arm terminal block between T5 and T9 and between T6 and T8. (See Figure 9.)

Table C

CURRENT RANGE RESISTOR VALUES

For current range (mA):	Use Module:	Add Resistor value (ohms):	To convert to a VDC range of:
0 to 20	NL-740A	250	0 to 5
0 to 50	NL-740A	100	0 to 5
1 to 5	NL-740C	1000	1 to 5
4 to 20	NL-740C	250	1 to 5
10 to 50	NL-740C	100	1 to 5

The magnitude of the signal is equal to the output of the non-zero channel. Combine the outputs in the user program simply by adding the 2 outputs. The sign can be determined by examining which channel has a non-zero output. When the top channel is non-zero, it is a positive signal, and when the bottom channel is non-zero the signal is negative.

In this type of bi-polar application, 2 input registers are still required. Thus the thumbwheel switches, explained in Programming Note 11, must be set to **different** digits.

6. For the A/D input register to accurately reflect the analog input voltage, that voltage must remain stable—i.e. unchanged—during the sample integration time interval, which is 16.67 ms. If the analog input changes during this time, the result of the A/D conversion will be the time-averaged value of the analog input.

7. The Processor's input registers associated with the input channels will contain the value 0000 when:

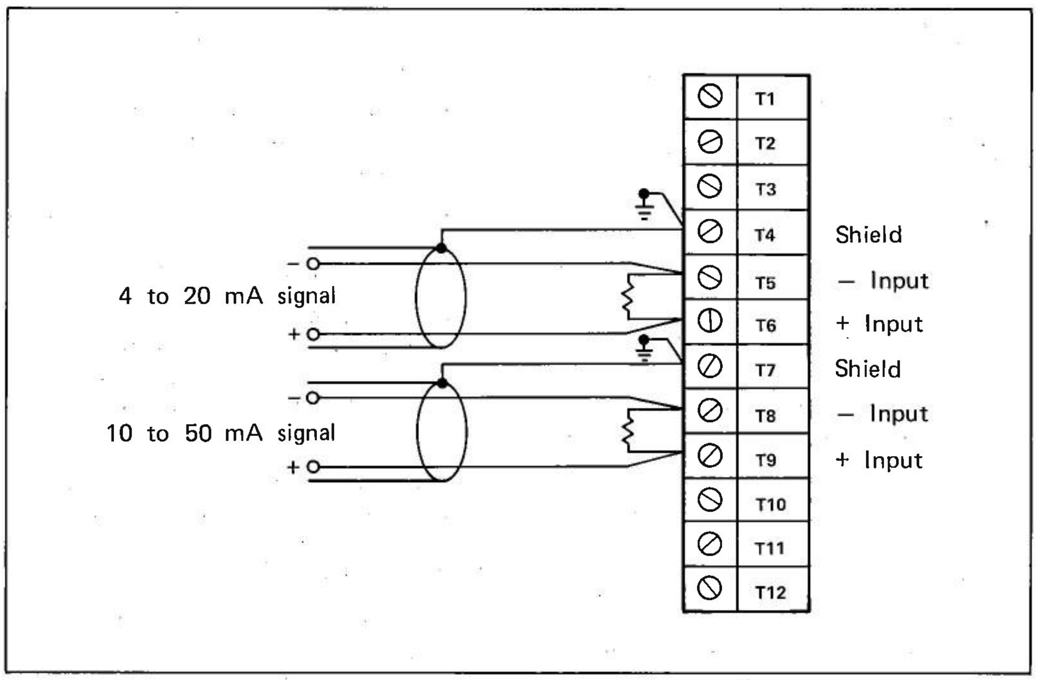

Figure 8 — Current Input Connections

- The polarity of the input connections are reversed, effectively inputting a negative voltage.
- The Module is removed from the I/O Rack. (The Processor does not sense a Module's absence.)
- The +12 VDC external power supply malfunctions or is disconnected while the Processor continues to operate normally.

8. In order to calculate the binary number sent to the input register that results from a given analog input, use one of the following formulas.

For NL-740A or B:

$$\text{binary number} = \frac{\text{analog input in VDC}}{\text{max. VDC (5 or 10)}} \times 4095$$

For NL-740C:

$$\text{binary number} = \frac{\text{analog input in VDC} - 1}{4.0} \times 4095$$

Example: Calculate the binary number resulting from a voltage of 2.0 VDC input to a NL-740A Module (0 to 5 V).

Answer: $\text{binary number} = \frac{2.0}{5.0} \times 4095$

binary number = 1638

9. The Module is designed to meet IEEE Surge Withstand Circuitry Standard 472-1974. Its circuitry minimizes the effects of high-voltage induced spikes up to 2.5 kV. Conversion accuracy may be reduced for as long as 16.7 sec. in some cases after a high-magnitude surge.

10. The Module requires the exclusive use of 2 Processor input registers. Note that it is possible to configure an application that requires more registers than are available in a specific Processor. Before designing a system, refer to the Series 700 and 900 Application Manuals for specific Processor register capability.

Also note that it is important to choose input registers that are numbered sequentially **and** within the same GSEL grouping as outlined in Table A. In other words, it would be unacceptable to use the Reference Numbers IR0008 and IR0009 to identify the 2 channels of this Module.

11. Thumbwheels near the rear edge of the Module identify each circuit with respect to a specific Reference Number and input register. When looking at the Module so that the label is readable, the lower thumbwheel identifies the bottom channel; the higher thumbwheel identifies the top channel. See Figure 3 and Table B. Exact settings must be supplied on system drawings to aid installation teams.

PROGRAMMING NOTES

1. If either an over- or under-range status condition is needed in a user program, consider the input register values 0000 and 4095 as under- and over-range signals, respectively. An input voltage **above** the full-scale rating for the Module results in a value of 4095—the identical value as a full scale input. An input voltage of 0 VDC, or less, results in an input register value of 0000. Note: if the analog input greatly exceeds the full-scale range, bit 16 can be set, thus indicating an error condition, as described in Programming Note 4.

2. The binary data from the A/D Input Module can be scaled by the user program by means of the special math functions. The resulting value will be a range of numbers from zero to some number less than 4095. The following formula may be used to perform scaling:

$$\text{scaled value} = \frac{\text{input register contents} \times \text{desired full-scale number}}{4095}$$

Example: A 0 to 10 VDC analog input originating from a 200.0 mm length gauge can be calibrated to indicate a range from 0 to 2000.0. (Here 0 VDC = 000.0 mm and 10 VDC = 200.0 mm.) Applying the above formula, the user program would multiply the input register value by 2000 and then divide the result by 4095. The final value could be used directly by an output device such as a

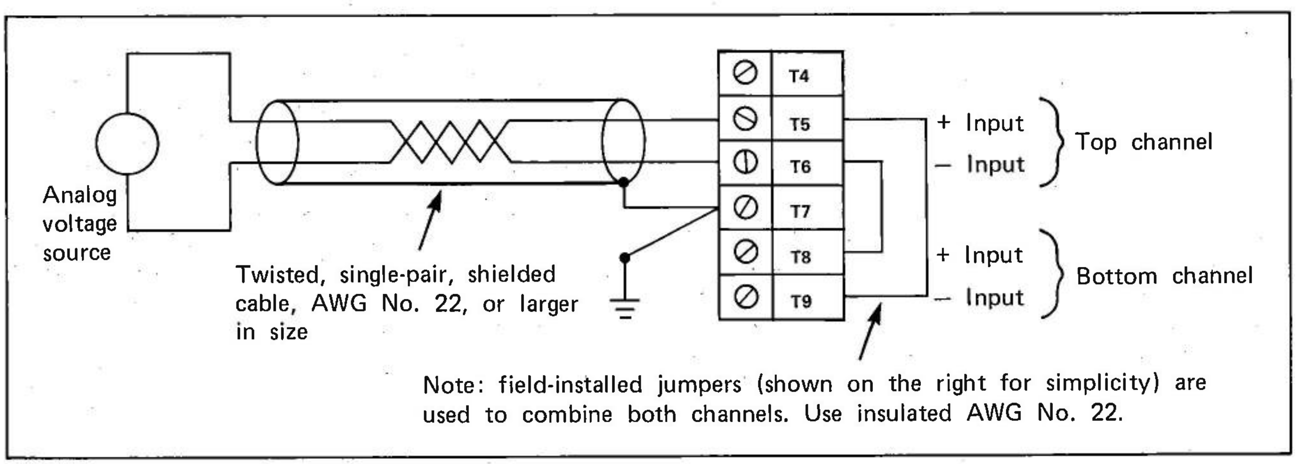

Figure 9 — Bi-polar Input Connections

printer or LED display. It may also be used in the program itself.

3. System response time is, to a certain extent, a variable. (System response is defined as the amount of time required after a change of an input voltage's state at a field terminal, for a corresponding change of state within the Processor.) To determine this time, it is necessary to add the maximum A/D converter response time of 33 ms to the time required by the Processor to make 1 scan. A typical Processor scan time is about 10 ms for each 1000 words of memory.

4. As the result of on-board malfunction detection circuitry, the Module can output a signal to the Processor that sets to Logic "1" (high) bit 16 of the input registers associated with the data channels. The setting of the malfunction bit creates an artificial value of 32,768. This causes the Processor to operate incorrectly since the A/D input value will **always** be greater during a "greater than" comparison.

To prevent this situation, the user program must be written to detect the setting of bit 16 and to initiate precautions in the program such as holding outputs ON or entering an emergency stop condition.

FUNCTIONAL THEORY

The Module contains 2 separate and isolated converters along with associated storage output latches. Analog inputs are converted to binary numbers ranging from 0, the minimum input, to 4095, the maximum input; the numbers are then stored in output latches. The Processor accesses the values in the latches during the I/O scan, thereby transferring the contents to the input registers assigned to the 2 channels of the Module. The Processor can then access the registers to perform further program functions.

Power Up — The logic of the Module is powered entirely by the external power supplies. When the +5.8 and 12.0 VDC supplies are energized and operational, the Module performs the following power-up routine:

- Data in the output latches is cleared.
- The A/D offset is read and the results are stored in the offset register.
- Normal operation is begun.

Assuming that the external supplies and Processor are powered by the same AC source, the A/D conversion results will be available to the Processor when it completes its power-up cycle. (This assumes that the external supply voltages are operational within 750 ms—as is the nominal period with the recommended Westinghouse supplies.)

Power Down — When either a power-down failure or a power failure occurs, one of 2 results occurs:

- The +5.8 VDC supply decays before the +12 VDC supply. When the decaying voltage reaches the +5.6 VDC level, the output latches are held in their state at that moment. These contain the data of the last conversion, and are considered valid data. As further decay occurs, the latches change to zero, and the Processor may enter a fault condition.

  Should the voltage return to the +5.6 VDC at any time during the power-down cycle, the Module recovers and functions properly.

- The +12 VDC supply decays before the 5.8 VDC supply. When the decaying voltage reaches approximately +7.5 VDC, the data contained in the output latches becomes invalid, and malfunction bit 16 is set to Logic "1." It remains set until the voltage reaches the 2.7 VDC at which time the output latches will be reset to Logic "0."

  If the voltage returns to +8 VDC, or higher, the Module resumes normal operation, assuming the +5.8 VDC supply is operating normally.

Module Operation — Analog input voltages are converted to binary numbers ranging from 0 to 4095 at a 30 Hz/sec. rate. A separate offset measurement is performed every 16.7 sec. in order to measure imbalances in the A/D converter. This offset is automatically subtracted from the A/D converter output sent to a storage "register" (here called output latch) on the Module every 16.7 ms. During the I/O scan the Processor accesses the input register independently (that is, asynchronously) of the A/D converter's operation.

CIRCUIT DESCRIPTION

This description provides a quick overview of the Module's major circuit components and their functions. It is not necessary to read this information in order to install or use the unit. (See Figure 10.)

The Analog-to-Digital Module contains 2 separate A/D channels, here described as top and bottom. These channels each convert a separate analog input into a binary number. A conceptual diagram of the A/D converter is shown in Figure 10. Each block is briefly described here.

DC-to-DC Converters — Two separate ±15 VDC supplies receive the 12 VDC from the external power supply and produce the isolated + and -15 VDC. The converter, or chopper type supply, contains a transformer that provides isolation for each channel.

Input Section — Provides filtering and buffering of the analog input voltage. (See Figure 11.) The analog voltage is input to a low-pass filter consisting of 2K resistors and 0.01 μF capacitors. Diodes D1 and D2 limit the voltage swings of the signal to the voltage listed in Table D. The

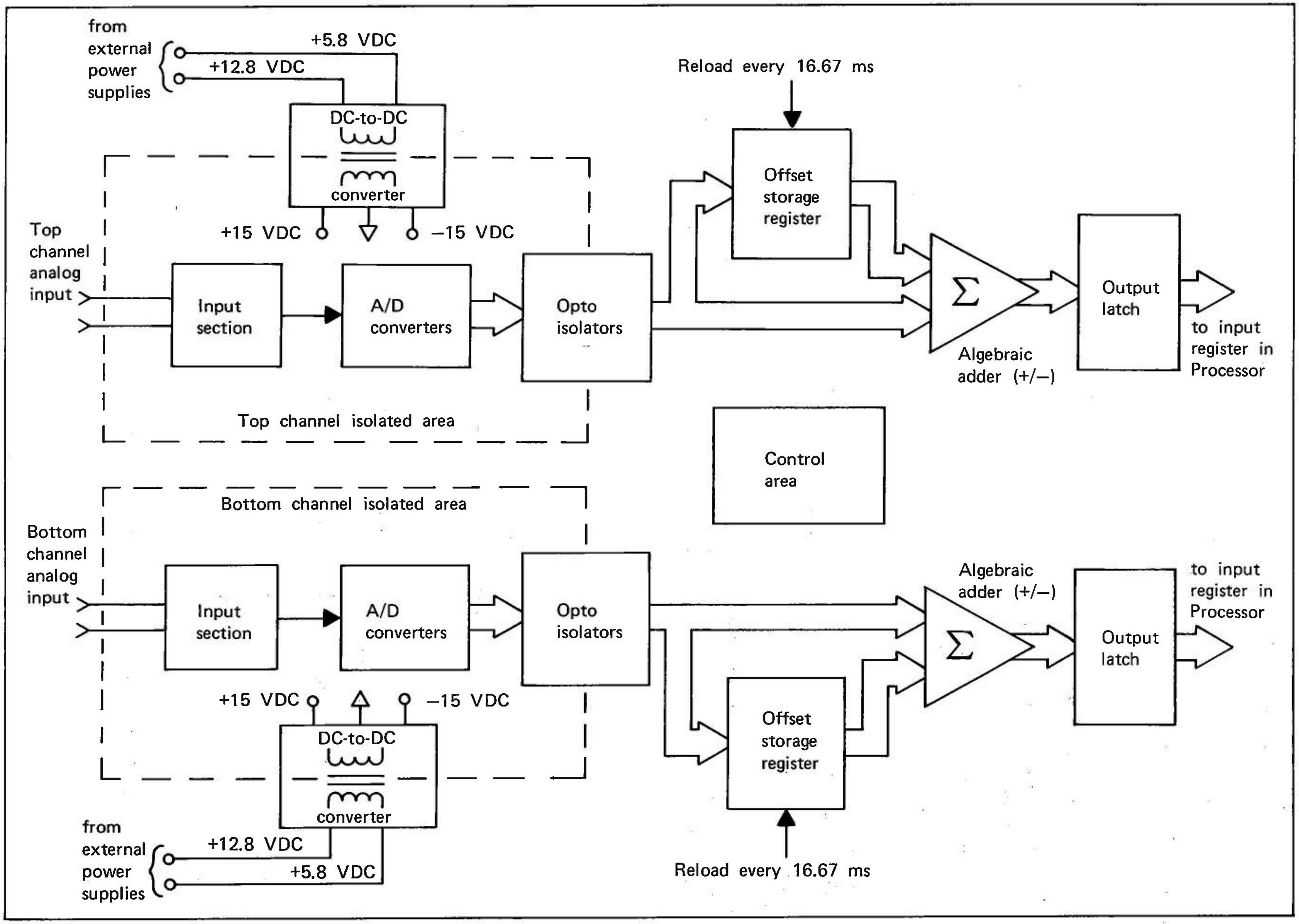

Figure 10 — A/D Module: Conceptual Diagram

non-inverting buffer amplifier provides the current gain that results in the A/D converter's high input impedance.

A/D Converter — Uses a dual-scale integration conversion technique charging a capacitor for a fixed period of time, which is the first slope; it then discharges the capacitor at a fixed rate, the second slope.

Table D

INPUT SIGNAL VOLTAGE LIMITS

NL Module Version	Voltage Limits (+ and - VDC)
-740A, C, D, E	±6.25
-740B	±14.7
-740F	±0.7

The time required to discharge the capacitor to zero volts is directly proportional to the value of the analog input voltage. This time is measured by a counter that will contain a value varying from 0 (for a 0 volt input) to 4095 (for a maximum-voltage input).

The charging time—i.e. first slope—is fixed at 16.67 ms. This time is specifically chosen to minimize the effects of any 60 Hz line frequencies that may be introduced into the analog input signal. (One 60 Hz cycle is 16.67 ms in duration.) Since the positive half of the AC line is offset by the negative half of each AC line cycle, a cancelling occurs during each measurement period, or first slope.

Opto Isolators — Transfers and electrically isolates the end-of-conversion signal from the A/D converter. Data is parallel transferred to the output latch.

Offset Storage Register — Stores the actual value of offset or inbalance resulting from component aging or component temperature coefficients. Once every 16.67 seconds the control section of the Module connects the A/D converter inputs to ground and stores the results of a conversion, which are the offset, in the offset register. Each subsequent A/D conversion "algebraically" (since offsets can be + or -) adds the offset register to the converter output, thereby obtaining the value stored in the output latch.

Output Latch — Stores the algebraic sum of the A/D conversion and offset register. This value is accessed by the Processor when it requests the data contained in the input register assigned to the Module.

Control Section — Coordinates the A/D converters and the loading of the output latches. It also provides for error checking of the Module and the setting of the malfunction flag bit in the register to indicate error.

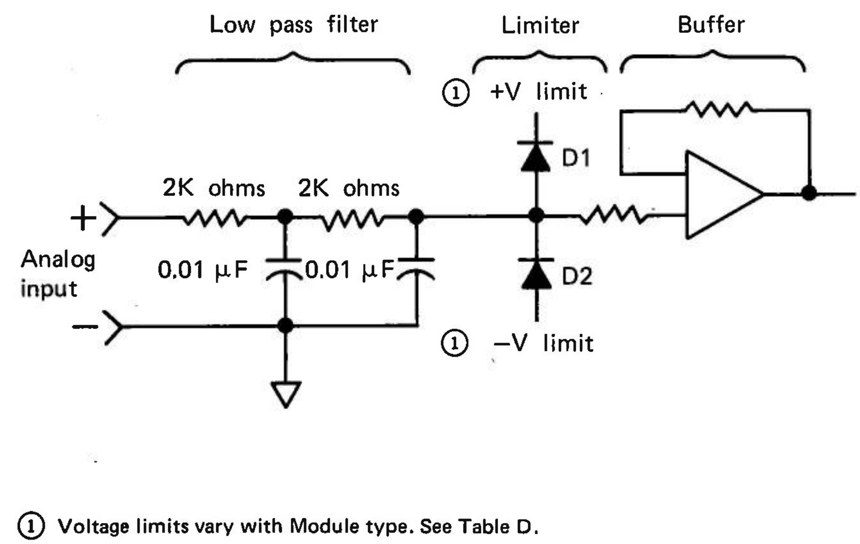

Figure 11 — A/D Input Section

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