F2-08AD-2
8-Channel Analog Voltage Input

Chapter 5

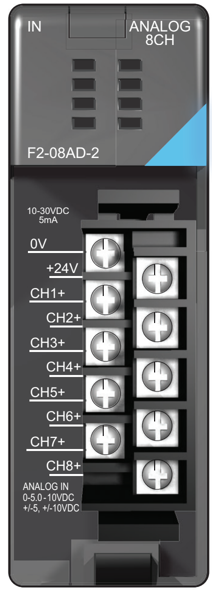
In This Chapter...

Module Specifications

***NOTE**: A re-designed F2-08AD-2 with a single circuit board design was released in 2009. The jumper link location is different. See Setting the Module Jumpers on page 5-6. Also, some specifications were changed on page 5-3. Otherwise, the re-designed module functions the same as the prior design.*

The F2-08AD-2 Analog Voltage Input module provides several hardware features:

- Analog inputs are optically isolated from the PLC logic.
- The module has a removable terminal block so the module can be easily removed or changed without disconnecting the wiring.
- With a DL240, DL250-1 or DL260 CPU, all channels can be updated in one scan.



Firmware Requirements:

To use this module, D2-230 CPUs must have firmware version 1.6 or later. To use the pointer method of writing values, D2-240 CPUs require firmware version 2.2 or later. All versions of the D2-250-1 and D2-260 CPU's firmware support this module and the pointer method.

Analog Input Configuration Requirements

The F2-08AD-2 Analog Input appears as a 16-point discrete input module. The module can be installed in any slot of a DL205 system. The available power budget and discrete I/O points are the limiting factors. Check the user manual for the CPU model and I/O base being used for more information regarding power budget and number of local, local expansion or remote I/O points.

The following tables provide the specifications for the F2–08AD–2 Analog Input Module. Review these specifications to make sure the module meets your application requirements.

Input Specifications	
Number of Channels	8, single ended (one common)
Input Ranges	0–5V, 0–10V, ±5V, ±10V
Resolution	12 bit (1 in 4096) unipolar (0 – 4095) 13 bit (1 in 8192) bipolar (– 4095 – +4095)
Step Response	1.0 ms (* 4 ms) – 95% of full step change
Crosstalk	–70 dB, 1 count maximum
Active Low-pass Filtering	–3 dB @ 200Hz (– 6 dB per octave)
Input Impedance	Greater than 20MΩ
Maximum Continuous Overload	-75 – +75VDC
Linearity Error (End to End)	±0.025% of span (±1 count maximum unipolar) (±2 count maximum bipolar)
Input Stability	±1 count
Full Scale Calibration Error (Offset error not included)	±3 counts maximum
Offset Calibration Error	±1 count maximum, @ 0VDC
Maximum Inaccuracy	±0.1% @ 25°C ±0.3% 0–60°C (32–140°F)
Accuracy vs. Temperature	±50 ppm/°C maximum full scale calibration (including maximum offset change of 2 counts)

* One count in the specification tables is equal to one least significant bit of the analog data value (1 in 4096).

General Specifications	
PLC Update Rate	1 channel per scan maximum (DL230 CPU) 8 channels per scan maximum (DL240/250 – 1/260 CPU)
Data Acquisition Time	3 ms/channel (asynchronous)
Digital Inputs Input points required	12 binary data bits, 1 sign bit 3 channel ID bits, 1 diagnostic bit 16 point (X) input module
Power Budget Requirement	100mA (* 60mA) maximum, 5VDC (supplied by base)
External Power Supply	5mA (* 80mA) maximum, 10–30 (* 18–26.4) VDC
Operating Temperature	0 –60°C (32–140°F)
Storage Temperature	-20–70°C (-4–158°F)
Relative Humidity	5–95% (non-condensing)
Environmental air	No corrosive gases permitted
Vibration	MIL STD 810C 514.2
Shock	MIL STD 810C 516.2
Noise Immunity	NEMA ICS3-304

***NOTE:** *Values in parenthesis with an asterisk are for older modules with two circuit board design and date codes 0609D4 and previous. Values not in parenthesis are for single circuit board models with date code 0709E1 and above.*

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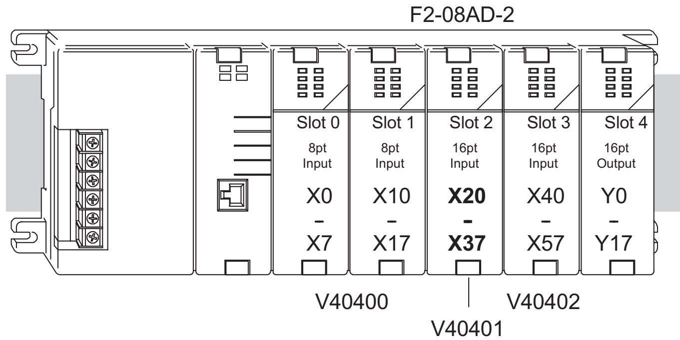
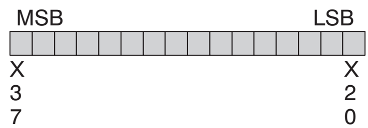
Special Placement Requirements (DL230 and Remote I/O Bases)

Even though the module can be placed in any slot, it is important to examine the configuration if a DL230 CPU is used, as can be seen in the section about **Writing the Program**, located in this chapter. V-memory locations are used to extract the analog data. If the module is placed so the input points do not start on a V-memory boundary, the instructions cannot access the data. This also applies when placing this module in a remote base using a D2-RSSS in the CPU slot.

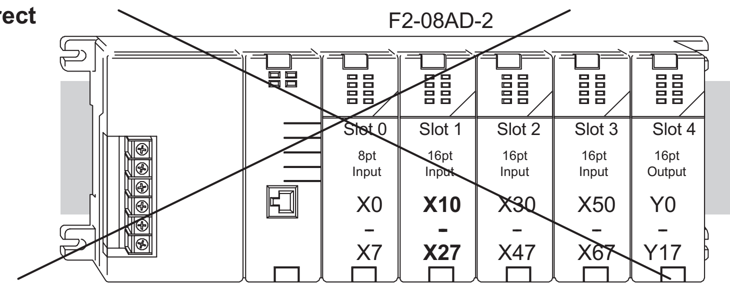
Correct!



Data is correctly entered so input points start on a V-memory boundary.



Incorrect



Data is split over two locations, so instructions cannot access data from a DL230.

To use the V-memory references required for a DL230 CPU, the first input address assigned to the module must be one of the following X locations. The table also shows the V-memory addresses that correspond to these X locations.

X	X0	X20	X40	X60	X100	X120	X140	X160
V	V40400	V40401	V40402	V40403	V40404	V40405	V40406	V40407

Setting the Module Jumpers

Selecting the Number of Channels

There are two jumpers, labeled +1, +2, and +4 that are used to select the number of channels that will be used. Use the figures below to locate the jumpers on the module. The module is set from the factory for eight channel operation (all jumpers installed).

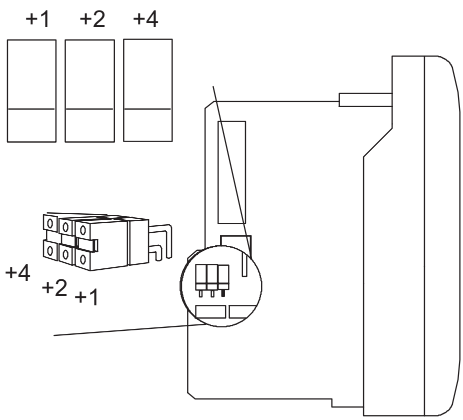
Unused channels are not processed. For example, if only channels 1 thru 3 are selected, then channels 4 through 8 will not be active. The following table shows how to place the jumpers to select the number of channels.

No. of Channels	+1	+2	+4
1	No	No	No
1, 2	Yes	No	No
1, 2, 3	No	Yes	No
1, 2, 3, 4	Yes	Yes	No
1, 2, 3, 4, 5	No	No	Yes
1, 2, 3, 4, 5, 6	Yes	No	Yes
1, 2, 3, 4, 5, 6, 7	No	Yes	Yes
1, 2, 3, 4, 5, 6, 7, 8	Yes	Yes	Yes

For example, to select all 8 channel operation, leave all jumpers installed. To select 1 channel, remove all three jumpers.
Note that removed jumpers can be stored on a single post to prevent from losing them.

Yes = jumper installed
No = jumper removed

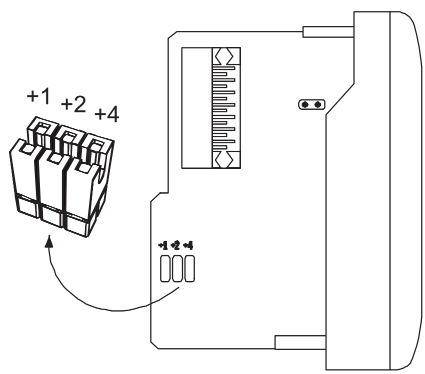
Jumper location on modules having Date Code 0609D4 and previous (two circuit board design)



These jumpers are located on the motherboard, the one with the black D-shell style backplane connector.

Jumper location on modules having Date Code 0709E1 and above (single circuit board design)

Use jumpers +1, +2 and +4 to select number of channels.

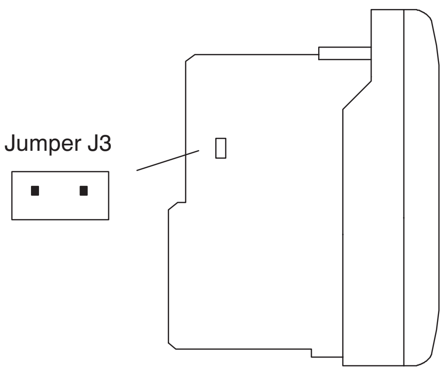


Selecting the Input Voltage

There is another jumper, labeled J3 that is used to select between the 5V ranges and the 10V ranges See the figures below to locate the jumper on the module being used. The module comes from the factory set for 10V operation (jumper is removed and is stored on one of the pins).

Install jumper J3 for 0–5V or ±5V operation.
Remove J3, or store on a single pin, for 0 to 10V or ±10V operation.

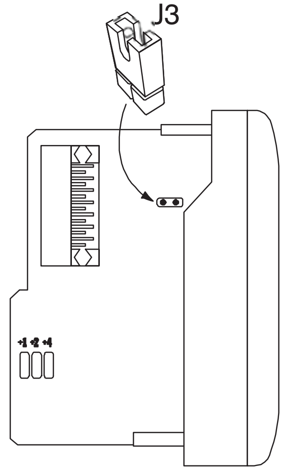
Jumper J3 location on modules having Date Code 0609D4 and previous (two circuit board design)



Jumper J3 is located on the smaller circuit board, which is on top of the motherboard.

Install J3 for 0–5V or ±5V operation.
Remove J3, or store on a single pin, for 0–10V or ±10V operation.

Jumper J3 location on modules having Date Code 0709E1 and above (single circuit board design)



Install J3 for 0–5V or ±5V operation.
Remove J3, or store on a single pin, for 0–10V or ±10V operation.

Connecting the Field Wiring

Wiring Guidelines

Your company may have guidelines for wiring and cable installation. If so, check them before starting the installation. Here are some general things to consider:

- Use the shortest wiring route whenever possible.
- Use shielded wiring and ground the shield at the transmitter source. *Do not* ground the shield at both the module and the source.
- Do not run the signal wiring next to large motors, high current switches, or transformers. This may cause noise problems.
- Route the wiring through an approved cable housing to minimize the risk of accidental damage. Check local and national codes to choose the correct method for your application.

User Power Supply Requirements

The same or separate power sources may be used for the current transmitter supply. The DL205 bases have built-in 24VDC power supplies that provide up to 300mA of current. This can be used instead of a separate supply if only a couple of analog modules are installed. Check the power budget to be safe.

It is desirable in some situations to power the transmitters separately in a location remote from the PLC. This will work as long as the transmitter supply meets the voltage and current requirements, and the transmitter's minus (-) side and the module supply's minus (-) side are connected together.

WARNING: If the 24VDC base power supply is used, Be sure to calculate the power budget. Exceeding the power budget can cause unpredictable system operation that can lead to a risk of personal injury or damage to equipment.

The DL205 base has a switching type power supply. As a result of switching noise, ±3–5 counts of instability may be noticed in the analog input data if this power supply is used. If this is unacceptable, try using one of the following.

1. Use a separate linear power supply.
2. Connect the 24VDC common to the frame ground, which is the screw terminal marked on the screw terminal marked “G” on the base.

By using these methods, the input stability is rated at ±1 count.

Unused inputs should be shorted together and connected to common.

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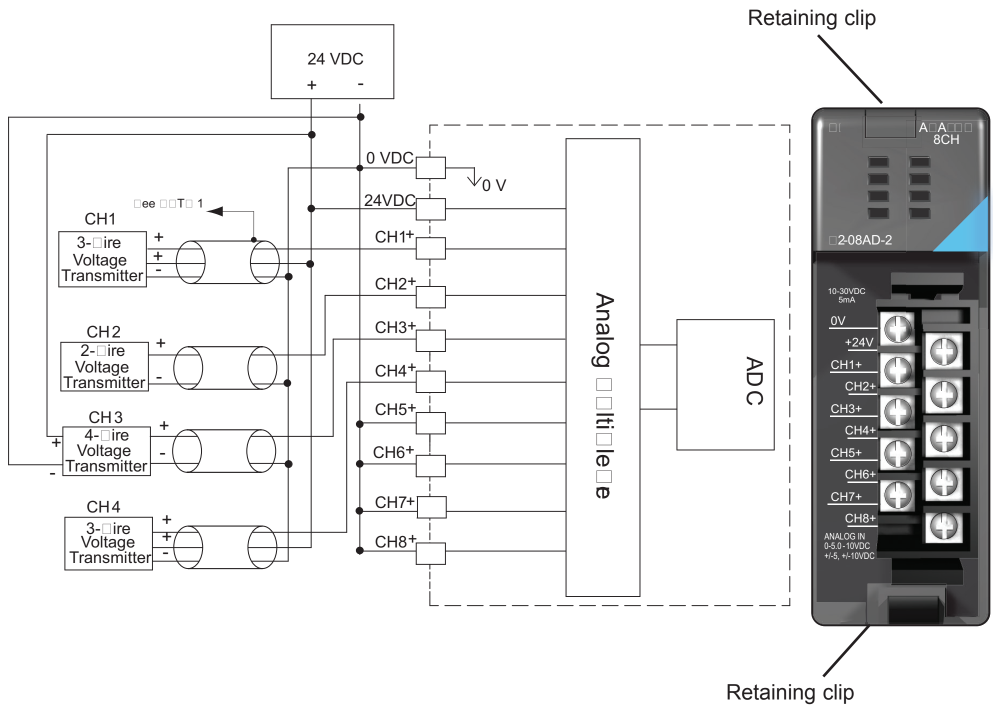
Wiring Diagram

The F2-08AD-2 module has a removable connector to simplify wiring the module. Just squeeze the top and bottom retaining clips and gently pull the connector from the module. Use the following diagram to connect the field wiring



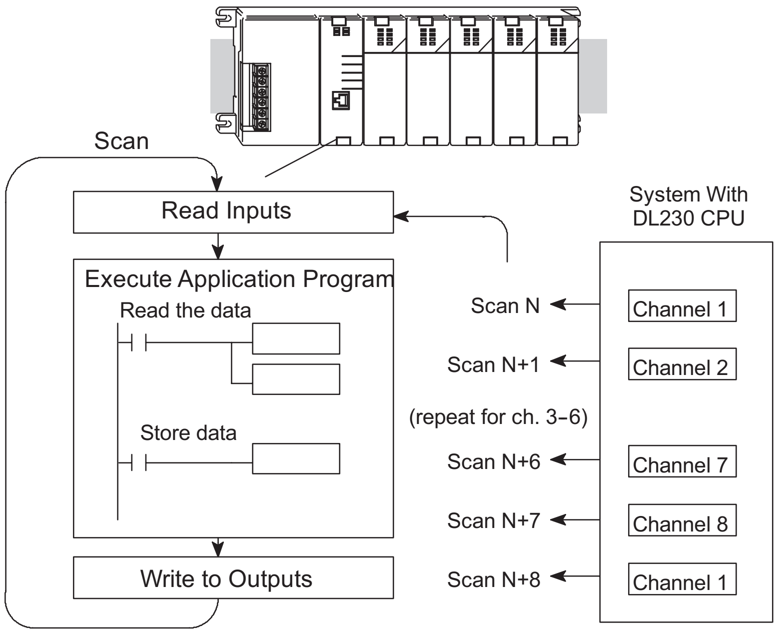
***NOTE: 1**. Connect unused channels (CH5+, CH6+, CH7+, CH8+ in this diagram) to common (0VDC).*

Module Operation

Channel Scanning Sequence for a DL230 CPU (Multiplexing)

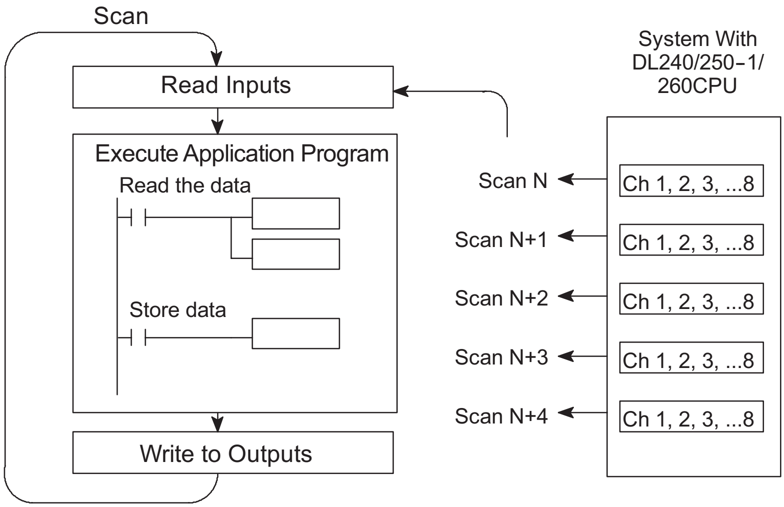
Before beginning to write the control program, it is important to take a few minutes to understand how the module processes and represents the analog signals.

Depending on the type of CPU being used, the F2-08AD-2 module can supply different amounts of data per scan. The DL230 can obtain one channel of data per CPU scan. Since there are eight channels, it can take up to eight scans to get data for all channels. Once all channels have been scanned the process starts over with channel 1. Unused channels are not processed, so if only two channels are selected, each channel will be updated every other scan. The multiplexing method can also be used for the DL240/250-1 and DL260 CPUs.



Channel Scanning Sequence for a DL240, DL250-1 or DL260 CPU (Pointer method)

If either a DL240, a DL250-1, or a DL260 CPU are used, all eight channels of input data can be collected in one scan. This is because the DL240, DL250-1 DL260 CPUs support special V-memory locations that are used to manage the data transfer which is discussed in more detail in the section on Writing the Control Program.



Analog Module Updates

Even though the channel updates to the CPU are synchronous with the CPU scan, the module asynchronously monitors the analog transmitter signal and converts the signal to a 12-bit binary representation. This enables the module to continuously provide accurate measurements without slowing down the discrete control logic in the RLL program.

For the vast majority of applications, the values are updated much faster than the signal changes. However, in some applications, the update time can be important. The module takes approximately 4 milliseconds to sense 95% of the change in the analog signal.

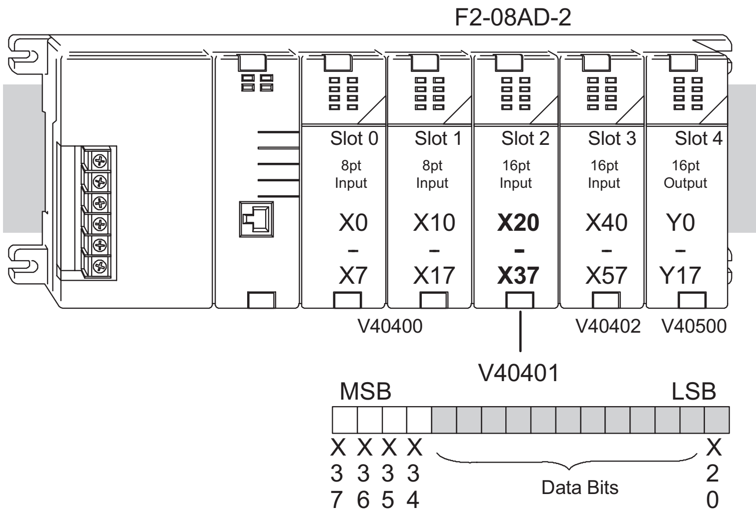
NOTE: *This is not the amount of time required to convert the signal to a digital representation. The conversion to the digital representation takes only a few microseconds. Many manufacturers list the conversion time, but it is the settling time of the filter that really determines the update time.*

Understanding the Input Assignments

It was mentioned earlier in this chapter that the F2-08AD-2 module appears as a 16-point discrete input module to the CPU. These points can be used to obtain:

- an indication of which channel is active
- the digital representation of the analog signal
- module diagnostic information

Since all input points are automatically mapped into V-memory, it is very easy to determine the location of the data word that will be assigned to the module.

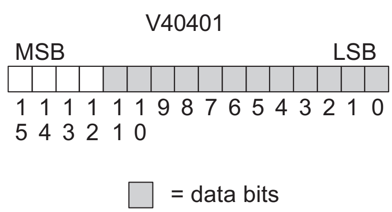


Within these word locations, the individual bits represent specific information about the analog signal.

Analog Data Bits

The first twelve bits represent the analog data in binary format.

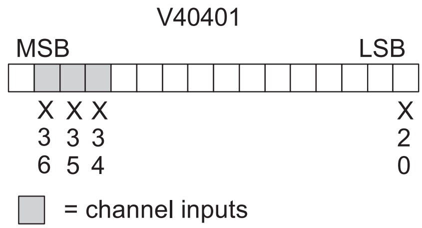
Bit	Value	Bit	Value
0	1	6	64
1	2	7	128
2	4	8	256
3	8	9	512
4	16	10	1024
5	32	11	2048



Active Channel Indicator Inputs

Two of the inputs are binary-encoded to indicate the active channel (remember, the V-memory bits are mapped directly to discrete inputs). The inputs automatically turn on and off to indicate the current channel for each scan.

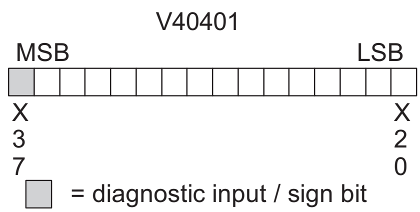
Scan	X34	X35	X36	Channel
N	Off	Off	Off	1
N+1	On	Off	Off	2
N+2	Off	On	Off	3
N+3	On	On	Off	4
N+4	Off	Off	On	5
N+5	On	Off	On	6
N+6	Off	On	On	7
N+7	On	On	On	8



Module Diagnostic and Sign

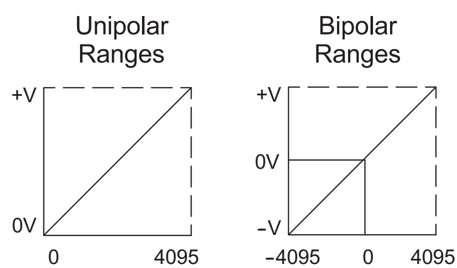
The MSB input bit is the broken transmitter/no 24V indicator and the sign indicator.

If the bit is on and the data is zero, there is no 24V input power or the terminal block is loose or missing. If the data is not 0 (zero), the input represents the sign bit.



Module Resolution

Since the module has 12-bit unipolar resolution, the analog signal is converted into 4096 counts ranging from 0–4095 (2^{12}). For example, with a 0–10V scale, a 0V signal would be 0, and a 10V signal would be 4095. This is equivalent to a binary value of 0000 0000 0000 to 1111 1111 1111, or 000 to FFF hexadecimal. The diagram shows how this relates to each signal range. The bipolar ranges utilize a sign bit to provide 13-bit resolution. A value of 4095 can represent the upper limit of either side of the range. Use the sign bit to determine negative values.



$$\text{Unipolar Resolution} = \frac{H - L}{4095}$$

$$\text{Bipolar Resolution} = \frac{H - L}{8191}$$

H or L = high or low limit of the range

Each count can also be expressed in terms of the signal level by using the equation shown on the facing page. The following table shows the smallest detectable signal change that will result in one LSB change in the data value for each input signal range.

Voltage Range	Signal Span (H – L)	Divide By	Smallest Detectable Change
0V– +10V	10V	4095	2.44 mV
-10V– +10V	20V	8191	2.44 mV
0V– +5V	5V	4095	1.22 mV
-5V– +5V	10V	8191	1.22 mV

Writing the Control Program

Reading Values: Pointer Method and Multiplexing

There are two methods of reading values:

- The pointer method
- Multiplexing

The multiplexing method must be used when using a DL230 CPU. The multiplexing method must also be used with remote I/O modules (the pointer method will not work). Either method can be used with the DL240, DL250-1 and DL260 CPUs, but for ease of programming it is strongly recommended to use the pointer method.

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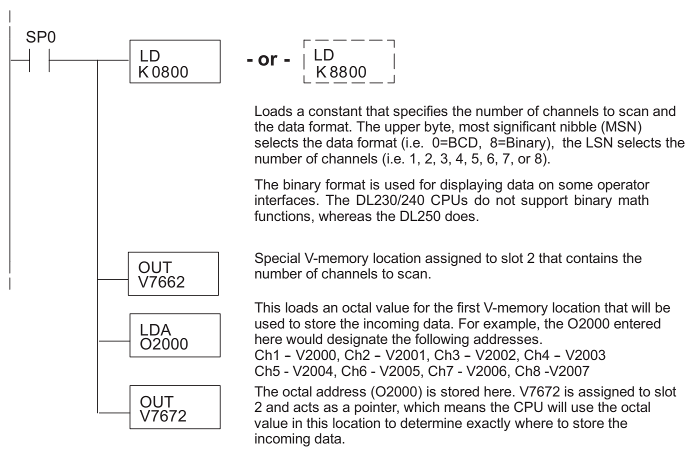
Pointer Method for the DL240, DL250-1 and DL260 CPUs

The DL205 series has special V-memory locations assigned to each base slot that will greatly simplify the programming requirements. These V-memory locations allow you to:

- specify the data format
- specify the number of channels to scan
- specify the storage locations

NOTE: *DL240 CPUs with firmware release version 2.2 or later support this method. DL250 CPUs with firmware release version 1.06 or later support this method. If the DL230 example needs to be used, module placement in the base is very important. Review the section earlier in this chapter for guidelines.*

The example program shows how to setup these locations. Place this rung anywhere in the ladder program, or in the initial stage if stage programming instructions are being used. This is all that is required to read the data into V-memory locations. Once the data is in V-memory math can be used on the data, compare the data against preset values, and so forth. V2000 is used in the example but any user V-memory location can be used. In this example the module is installed in slot 2. Be sure to use the V-memory locations for the module placement. The pointer method automatically converts values to BCD (depending on the LD statement in the ladder logic).



The tables below show the special V-memory locations used by the DL240, DL250-1 and DL260 for the CPU base and local expansion base I/O slots. Slot 0 (zero) is the module next to the CPU or D2-CM module. Slot 1 is the module two places from the CPU or D2-CM, and so on. Remember, the CPU only examines the pointer values at these locations after a mode transition. Also, if you use the DL230 (multiplexing) method, verify that these addresses in the CPU are 0 (zero).

The Table below applies to the DL240, DL250-1 and DL260 CPU base.

CPU Base: Analog Input Module Slot-Dependent V-memory Locations								
Slot	0	1	2	3	4	5	6	7
No. of Channels	V7660	V7661	V7662	V7663	V7664	V7665	V7666	V7667
Storage Pointer	V7670	V7671	V7672	V7673	V7674	V7675	V7676	V7677

The Table below applies to the DL250-1 or the DL260 CPU base 1.

Expansion Base D2-CM #1: Analog Input Module Slot-Dependent V-memory Locations								
Slot	0	1	2	3	4	5	6	7
No. of Channels	V36000	V36001	V36002	V36003	V36004	V36005	V36006	V36007
Storage Pointer	V36010	V36011	V36012	V36013	V36014	V36015	V36016	V36017

The Table below applies to the DL250-1 or the DL260 CPU base 2.

Expansion Base D2-CM #2: Analog Input Module Slot-Dependent V-memory Locations								
Slot	0	1	2	3	4	5	6	7
No. of Channels	V36100	V36101	V36102	V36103		V36105	V36106	V36107
Storage Pointer	V36110	V36111	V36112	V36113	V36114	V36115	V36116	V36117

The Table below applies to the DL260 CPU base 3.

Expansion Base D2-CM #3: Analog Input Module Slot-Dependent V-memory Locations								
Slot	0	1	2	3	4	5	6	7
No. of Channels	V36200	V36201	V36202	V36203	V36204	V36205	V36206	V36207
Storage Pointer	V36210	V36211	V36212	V36213	V36214	V36215	V36216	V36217

The Table below applies to the DL260 CPU base 4.

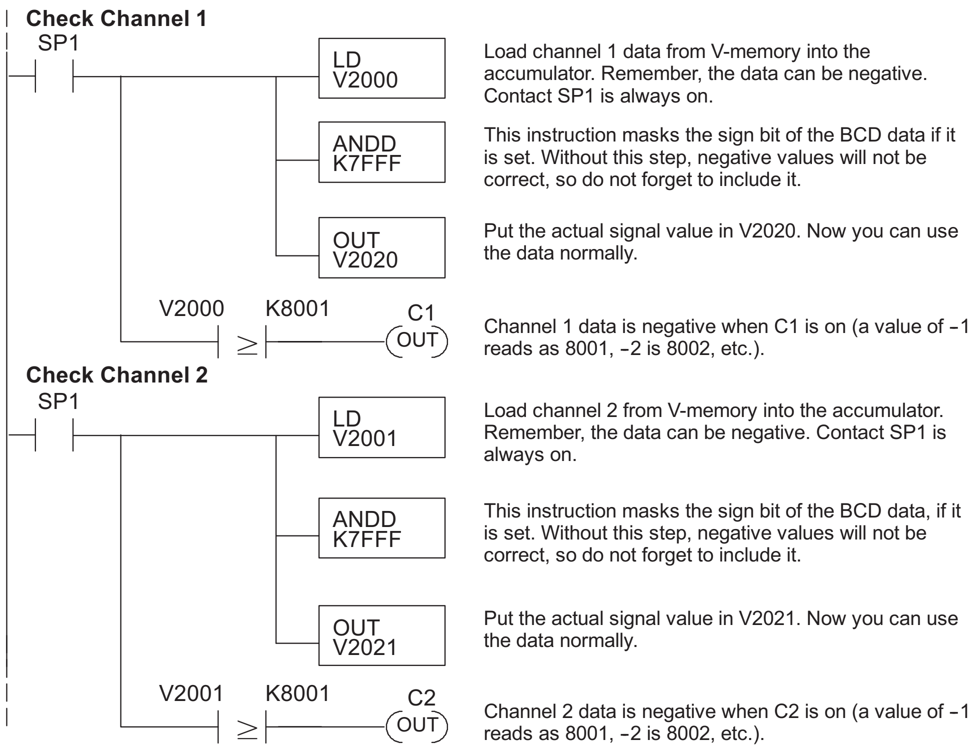
Expansion Base D2-CM #4: Analog Input Module Slot-Dependent V-memory Locations								
Slot	0	1	2	3	4	5	6	7
No. of Channels	V36300	V36301	V36302	V36303	V36304	V36305	V36306	V36307
Storage Pointer	V36310	V36311	V36312	V36313	V36314	V36315	V36316	V36317

Using Bipolar Ranges (Pointer Method) for the DL240, DL250-1 and DL260 CPUs

Some additional logic is needed with bipolar ranges to determine whether the value being returned represents a positive voltage or a negative voltage. For example, the direction of a motor may be needed to be known. With the DL240/250 CPU, the last input cannot be used to show the sign for each channel (X37 in the previous examples). This is because the DL240/250-1/260 reads all eight channels in one scan. Therefore, if X37 were used, the last channel read would just be monitored and the sign would not be able to be determined for the previous channels. A simple solution is if the value read is greater than or equal to 8001 the value is negative.

The sign bit is the most significant bit, which combines 8000 with the data value. If the value is greater than or equal to 8001, only the most significant bit and the active channel bits will need to be masked to determine the actual data value.

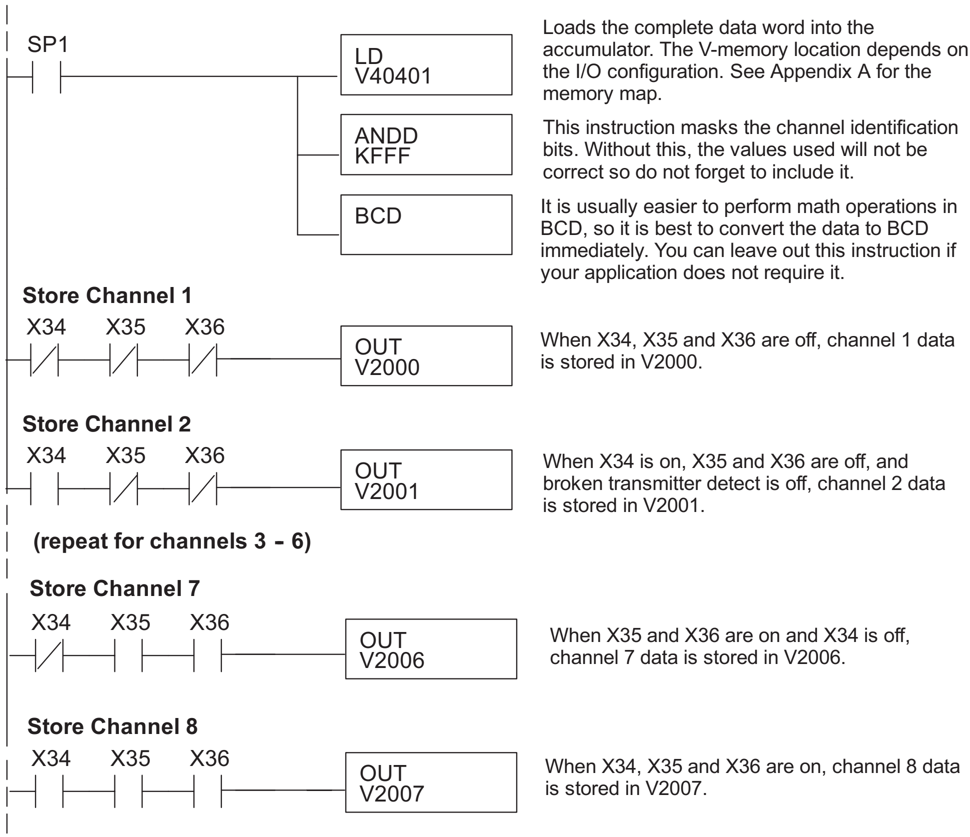
The following program shows how to accomplish this. Since a negative value is always meant to be known, these rungs should be placed before any other operations that use the data, such as math instructions, scaling operations, and so forth. Also, if stage programming instructions are being used, place these rungs in a stage that is always active. Please note, this logic is only needed for each channel that is using bipolar input signals. The following example only shows two channels.



Reading Values (Multiplexing) for the DL230, DL240, DL250-1 and DL260

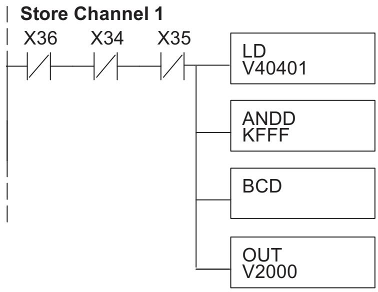
The DL230 CPU does not have the special V-memory locations which will allow data transfer to be automatically enabled. Since all channels are multiplexed into a single data word, the control program must be setup to determine which channel is being read. Since the module appears as X input points to the CPU, it is very easy to use the active channel status bits to determine which channel is being monitored.

NOTE: *This example is for a module installed as shown in the previous examples. The addresses used would be different if the module is installed in a different I/O arrangement. The rungs can be placed anywhere in the program, or if stage programming is being used, place them in a stage that is always active.*



Single Channel Selected

The single channel program makes it easy to determine which channel has been selected.



Loads the complete data word into the accumulator. The V-memory location depends on the I/O configuration. See Appendix A for the memory map.

This instruction masks the channel identification bits. Without this, the values used will not be correct, so do not forget to include it.

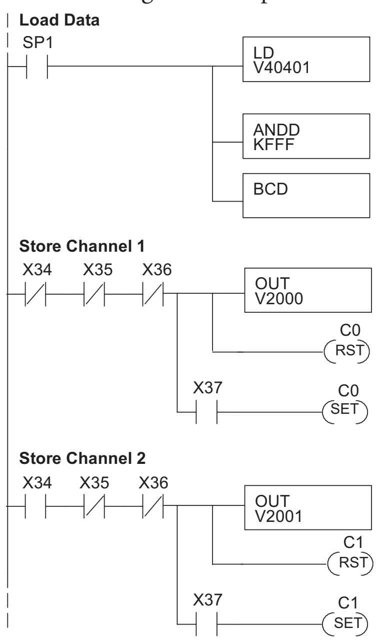
It is usually easier to perform math operations in BCD. So it is best to convert the data to BCD immediately. You can leave out this instruction if your application does not require it.

When the module is not busy, and X34 and X35 are off, channel 1 data is stored in V2000.

Using Bipolar Ranges (Multiplexing)

Some additional logic is needed with bipolar ranges to determine whether the value being returned represents a positive voltage or a negative voltage. For example, the direction of a motor may be needed to be known. Since the DL230 only reads one channel per scan, the last input can be used to show the sign (X37 in the examples).

The following program shows how to accomplish this. Since a negative value is always needed to be known, these rungs should be placed before any other operations that use the data, such as math instructions, scaling operations, and so forth. Also, if stage programming instructions are being used, place these rungs in a stage that is always active. Please note, this logic is only needed for each channel that is using bipolar input signals. The following example only shows two channels but the rungs can be repeated for all eight channels if needed.



Loads the complete data word into the accumulator. The V-memory location depends on the I/O configuration. See Appendix A for the memory map.

This instruction masks the channel identification bits. Without this, the values used will not be correct, so do not forget to include it.

It is usually easier to perform math operations in BCD, so it is best to convert the data to BCD immediately. You can leave out this instruction if your application does not require it.

When the module is not busy, and X34, X35 and X36 are off, channel 1 data is stored in V2000. C0 is reset to indicate channel 1's value is positive.

If X37 is on, then the data value represents a negative voltage. C0 is set to indicate channel 1's value is negative.

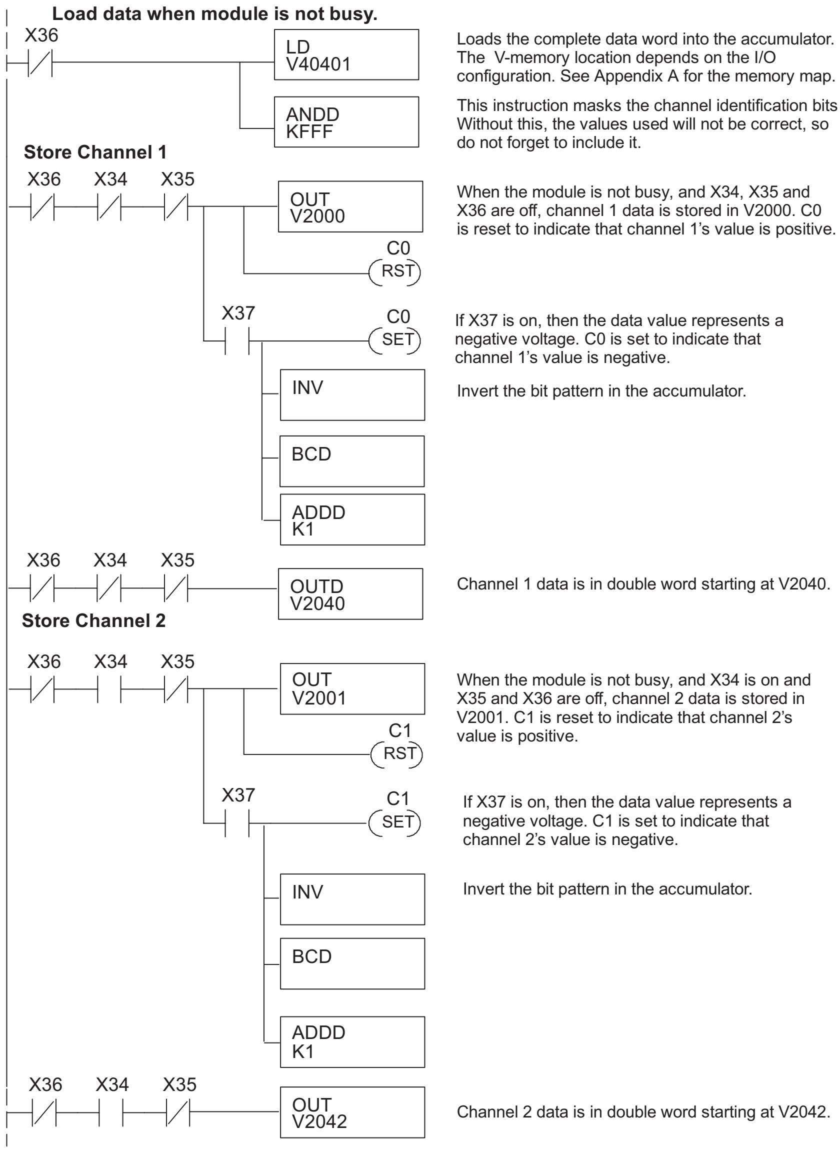
When the module is not busy, and X34 is on and X35 and X36 are off, channel 2 data is stored in V2001. C1 is reset to indicate channel 2's value is positive.

If X37 is on, then the data value represents a negative voltage. C1 is set to indicate channel 2's value is negative.

Using 2's Complement for the DL230, DL240, DL250-1, and the DL260 CPUs (Multiplexing)

The 2's complement data format may be required to display negative values on some operator interface devices. It could also be used to simplify data averaging on bipolar signals.

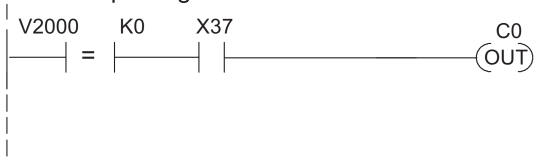
The example shows two channels, but these steps can be repeated for all eight channels if necessary.



Analog Power Failure Detection

The analog module has a microcontroller which can diagnose analog input circuit problems. A ladder rung can be added to program to detect these problems. This rung shows an input point that would be assigned if the module was used as shown in the previous examples. A different point would be used if the module was installed in a different I/O configuration.

Multiplexing method



V-memory location V2000 holds channel 1 data. When a data value of zero is returned and input X37 is on, then the analog circuitry is not operating properly.

Pointers method

V-memory location V2000 holds channel 1 data. When a data value of 8000 is returned, then the analog circuitry is not operating properly.

Scaling the Input Data

Most applications usually require measurements in engineering units which provides more meaningful data. This is accomplished by using the conversion formula shown.

Adjustments may be needed to the formula depending on the scale being used for the engineering units.

$$\text{Units} = A\,\frac{H - L}{4095}$$

U = Engineering Units

A = Analog Value (0 – 4095)

H = High limit of the engineering unit range

L = Low limit of the engineering unit range

For example, if pressure (PSI) is to be measured from 0.0–99.9 then multiply the value by 10 in order to imply a decimal place when viewing the value with the programming software or with a handheld programmer. Notice how the calculations differ when the multiplier is used.

Analog Value of 2024, slightly less than half scale, should yield 49.4 PSI.

Example without multiplier

$$\text{Units} = A\,\frac{H - L}{4095}$$

$$\text{Units} = 2024\,\frac{100 - 0}{4095}$$

$$\text{Units} = 49$$

Example with multiplier

$$\text{Units} = 10A\,\frac{H - L}{4095}$$

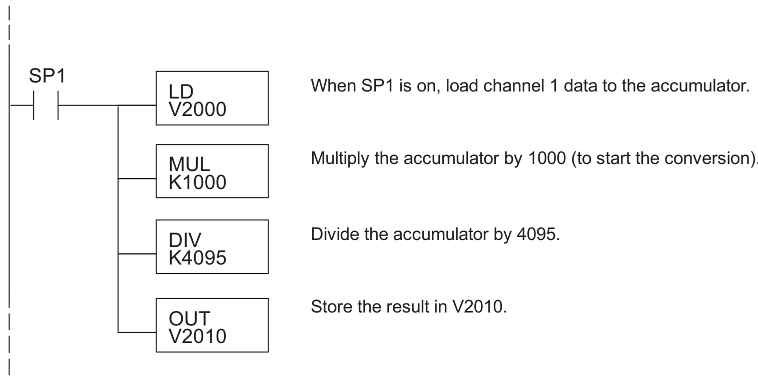
$$\text{Units} = 20240\,\frac{100 - 0}{4095}$$

$$\text{Units} = 494$$

The Conversion Program

The following example shows how to write the program to perform the engineering unit conversion. This example assumes the raw input data read at V2000 is in BCD format.

NOTE: *This example uses SP1, which is always on, but any permissive contact such as, X, C, etc., can be used.*



Analog and Digital Value Conversions

Sometimes it is useful to be able to quickly convert between the signal levels and the digital values. This is especially helpful during machine startup or troubleshooting. Remember, that this module does not operate like other versions of analog input modules. The bipolar ranges use 0-4095 for both positive and negative voltages. The sign bit allows this, which actually provides better resolution than those modules that do not offer a sign bit. The following table provides formulas to make this conversion easier.

Range	If the digital value is known	If the analog signal level is known.
0–5V -5V– +5V	$A = \frac{5D}{4095}$	$D = \frac{4095}{5}(A)$
0–10V -10V – +10 V	$A = \frac{5D}{4095}$	$D = \frac{4095}{10}\text{ABS}(A)$

As an example, if the range being used is -10V – +10V and the measured signal is 6V, use the formula to the right to determine the digital value that is stored in the V-memory location that contains the data.

$$D = \frac{4095}{10}(A)$$

$$D = \frac{4095}{10}(6V)$$

$$D = (409.5)(6)$$

$$D = 2457$$

Filtering Input Noise for the DL250-1 and DL260 CPUs Only

Add the following logic to filter and smooth analog input noise in DL250-1 and DL260 CPUs. This is especially useful when using PID loops. Noise can be generated by the field device and or induced by field wiring.

The analog value in BCD is first converted to a binary number because there is not a BCD-to-real conversion instruction. Memory location V1400 is the designated work space in this example. The MULR instruction is the filter factor, which can be from 0.1–0.9. The example uses 0.2. A smaller filter factor increases filtering. A higher precision value can be used, but it is not generally needed. The filtered value is then converted back to binary and then to BCD. The filtered value is stored in location V1402 for use in your application or PID loop.

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NOTE: *Be careful not to do a multiple number conversion on a value. For example, if you are using the pointer method to get the analog value, it is in BCD and must be converted to binary. However, if you are using the conventional method of reading analog and are masking the first twelve bits, then it is already in binary and no conversion using the BIN instruction is needed.*