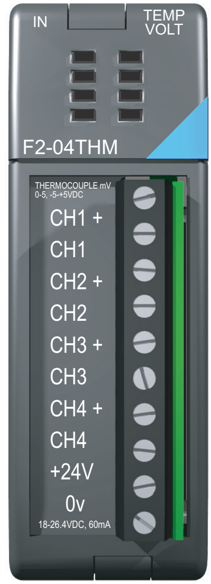
F2-04THM 4-Channel Thermocouple Input

Chapter 7

In This Chapter...

Module Specifications



The F2-04THM, 4-Channel Thermocouple Input Module provides the following features and benefits:

- Four thermocouple input channels with 16-bit voltage resolution or 0.1°F/°C temperature resolution.
- Automatically converts type E, J, K, R, S, T, B, N, or C thermocouple signals into direct temperature readings. No extra scaling or complex conversion is required.
- Temperature data can be expressed in °F or °C.
- Module can be configured as ±5V, ±156mV, 0–5V, 0–156mV input and will convert volts and millivolt signal levels into 16-bit digital (0–65535) values.
- Signal processing features include automatic cold junction compensation, thermocouple linearization, and digital filtering.
- The temperature calculation and linearization are based on data provided by the National Institute of Standards and Technology (NIST).
- Diagnostic features include detection of thermocouple burnout or disconnection.

The following tables provide the specifications for the F2-04THM Analog Input Module. Review these specifications to make sure the module meets your application requirements.

General Specifications	
Number of Channels	4, differential
Common Mode Range	±5VDC
Common Mode Rejection	90dB min. @ DC, 150dB min. @ 50/60Hz.
Input Impedance	1MΩ min.
Absolute Maximum Ratings	Fault-protected inputs to ±50VDC
Accuracy vs. Temperature	±5ppm/°C maximum; full scale calibration (including maximum offset change)
Sampling Rate	All 4 channels: 1.4 seconds (*5.4 seconds)
PLC Update Rate	4 channels per scan max. (D2-240, D2-250–1, D2-260 and D2-262 CPU) 1 channel per scan ,max. D2-230 CPU
Digital Inputs **Input Points Required**	16 binary data bits, 2 channel ID bits, 4 diagnostic bits 32 point (X) input module
Power Budget Requirement	80mA (*100mA) maximum, 5VDC (supplied by base)
External Power Supply	40 mA, 10-30 VDC (*60 mA, 18-26.4 VDC)
Operating Temperature	0–60°C (32–140°F)
Storage Temperature	-2°C to70°C (-4°F to158°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

Thermocouple Specifications			
Input Ranges	Type J	-190–760°C	(-310–1400°F)
	Type K	-150–1372°C	(-238–2502°F)
	Type E	-210–1000°C	(-346–1832°F)
	Type R	65–1768°C	(149–3214°F)
	*Type R Wide	65–1768°C	(149–3214°F)
	Type S	65–1768°C	(149–3214°F)
	Type T	-230–400°C	(-382–752°F)
	Type B	529–1820°C	(984–3308°F)
	Type N	-70–1300°C	(-94–2372°F)
	Type C	65–2320°C	(149–4208°F)
Display Resolution	±0.1°C or ±0.1°F		
Cold Junction Compensation	Automatic		
Warm-Up Time	30 minutes typically ±1°C repeatability		
Linearity Error (End to End)	±1°C maximum, ±0.5°C typical		
Maximum Inaccuracy	±3°C (excluding thermocouple error)		

NOTE: **R Wide range is available only on modules with date code 0410E2 and later.*
NOTE: *Values in parenthesis with an asterisk are for older modules with two circuit board design and date codes 0806E1 or previous. Values not in parenthesis are for single circuit board models with date code 0806E1 and above.*

Voltage Input Specifications	
Voltage Ranges	Voltage: 0-5V, ±5V, 0-156.25 mV, ±156.25 mVDC,
Resolution	16 bit (1 in 65535)
Full Scale Calibration Error (Offset Error Included)	±13 count typical, ±33 maximum
Offset Calibration Error	±1 count maximum @ 0V input
Linearity Error (End to End)	±1 count maximum
Maximum Inaccuracy	±0.02% @ 25°C (77°F)

Module Calibration

The F2-04THM module requires no calibration. The module automatically calibrates every five seconds, which removes offset and gain errors. For each thermocouple type, the temperature calculation and linearization performed by the microprocessor is accurate to within 0.01°C.

Thermocouple Input Configuration Requirements

The F2-04THM temperature input module requires 32 discrete input points. The module can be installed in any slot of a DL205 system. The limitations on the number of analog modules are:

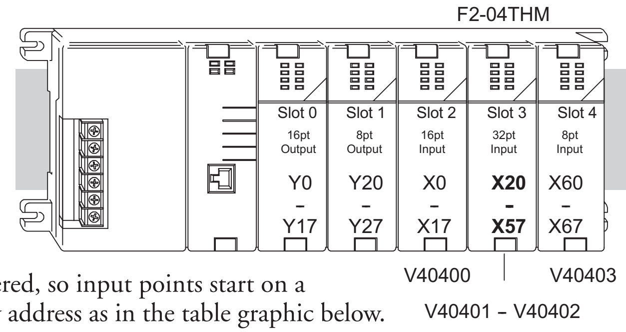
- For local and local expansion systems, the available power budget and number of discrete I/O points.
- For remote I/O systems, the available power budget and number of remote I/O points.

Check the user manual for the particular model of CPU and I/O base being used for more information regarding power budget and number of local, local expansion or remote I/O points.

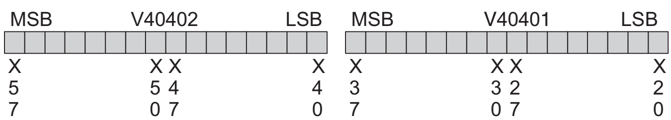
Special Placement Requirements (D2-230 and Remote I/O Bases)

It is important to examine the configuration if a D2-230 CPU is being used. As can be seen in the section on **Writing the Control Program**, V-memory locations are used to manage the analog data. If the module is placed in a slot so that the input points do not start on a V-memory boundary, the program instructions aren't able to access the data. This also applies when placing this module in a remote base using a D2-RSSS in the CPU slot.

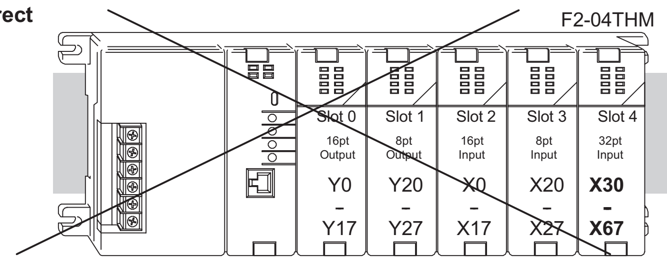
Correct!



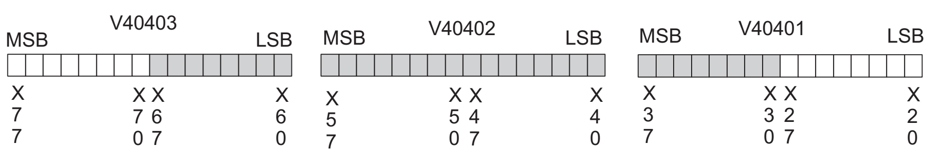
Data is correctly entered, so input points start on a V-memory boundary address as in the table graphic below.



Incorrect



Data is split over three locations, (see graphic below) so instructions cannot access data from a D2-230 CPU.



V-memory references required for a D2-230 CPU, the first input address assigned to the module must be one of the following X locations. The corresponding V-memory addresses for the X locations are shown below.

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

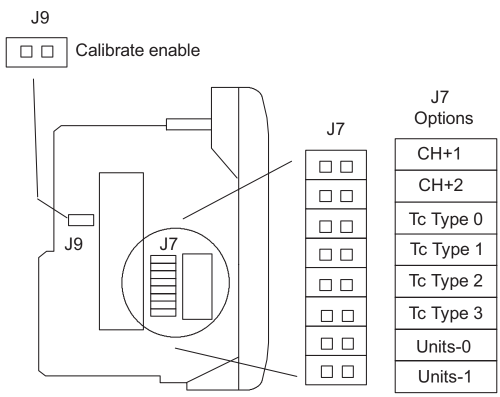
Setting the Module Jumpers

Jumper Locations

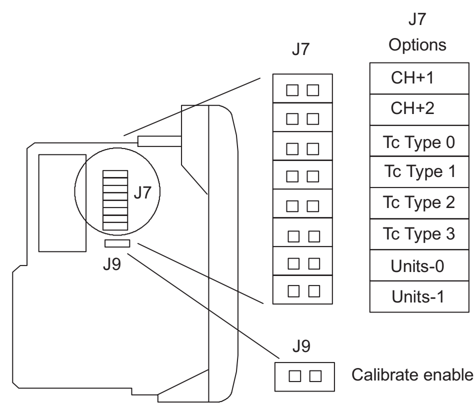
Use the figures below to locate the single jumper (J9) and the bank of eight jumpers (J7) on the PC board. Notice that the PC board was re-designed starting with date code 0806E1 and the jumper locations changed; the functionality of the jumpers did not change. To prevent losing a jumper when it is removed, store it in its original location by sliding one of its sockets over a single pin. The following options can be selected by installing or removing the appropriate jumpers:

- Number of channels
- Input type
- Conversion unit
- Calibrate enable

Jumper locations for modules having date code prior to 0806E1.



Jumper locations for modules having date code 0806E1 and later.



Calibrate Enable

Locate the “Calibrate enable” jumper J9. The jumper comes from the factory with the jumper removed (the jumper is installed on one of the two pins only). Installing this jumper disables the thermocouple active burn-out detection circuitry, which enables a thermocouple calibrator to be attached to the module.

To be certain that the output of the thermocouple calibrator is within the 5V common mode voltage range of the module, connect the negative side of the differential voltage input channel to the 0V terminal, then connect the thermocouple calibrator to the differential inputs (for example, Ch 3+ and Ch 3).

For the voltage input ranges, this jumper is inactive and can be installed or removed with no effect on voltage input.

Selecting the Number of Channels

The top two J7 jumpers labeled **CH+1** and **CH+2** determine the number of channels that will be used. The table shows how to set the jumpers for channels 1 to 4. The module comes with both jumpers installed for four channel operation. For example, to select channels 1 to 3, leave the **CH+2** jumper installed and remove the **CH+1** jumper. Any unused channels are not processed. For example, if channels 1 to 3 are selected, channel 4 will not be active.

X = jumper installed
Blank space = jumper removed

Number of Channels	Jumper	
	CH+1	CH+2
1	–	–
2	X	–
3	–	X
4	X	X

Setting Input Type

The next four jumpers, **Tc Type 0**, **Tc Type 1**, **Tc Type 2**, **and Tc Type 3**, must be set to match either the type of thermocouple being used or the input voltage level. Since the module can be used with many types of thermocouples, use the table below to determine the proper settings for the thermocouple being used.

The module comes from the factory with all four jumpers installed for use with a J type thermocouple. To use a K type thermocouple, remove the jumper labeled **Tc Type 0**.

NOTE: *All channels of the module must be the same thermocouple type or voltage range.*

X = Jumper installed, and blank space = Jumper removed.

Thermocouple/ Voltage Inputs	Jumper			
	Tc Type 0	Tc Type 1	Tc Type 2	Tc Type 3
J	X	X	X	X
K	–	X	X	X
E	X	–	X	X
R	–	–	X	X
R Wide*	–	X	–	–
S	X	X	–	X
T	–	X	–	X
B	X	–	–	X
N	–	–	–	X
C	X	X	X	–
0–5V	–	X	X	–
±5V	X	–	X	–
0–156 mV	–	–	X	–
±156 mV	X	X	–	–

****NOTE:*** *R Wide is only available on modules with date code 0410E2 and later.*

Selecting the Conversion Units

Use the last two jumpers, **Units-0** and **Units-1**, to set the conversion unit used for either thermocouple or voltage inputs. The options are magnitude plus sign or 2's complement, plus Fahrenheit or Celsius for thermocouples. See the next two sections for jumper settings when using either thermocouple or voltage inputs.

Thermocouple Conversion Units

All thermocouple types are converted into a direct temperature reading in either Fahrenheit or Celsius. The data contains one implied decimal place. For example, a value in V-memory of 1002 would be 100.2°F or °C.

For thermocouple ranges which include negative temperatures (J,E,K,T,N), the display resolution is from -3276.7 to +3276.7. For positive-only thermocouple ranges (R,S,B,C), the display resolution is 0 – 6553.5.

Negative temperatures can be represented in either 2's complement or magnitude plus sign form. If the temperature is negative, the most significant bit in the V-memory location is set (X17, if the starting address for the module is X0).

The 2's complement data format may be required to correctly display bipolar data on some operator interfaces. This data format could also be used to simplify averaging a bipolar signal. To view this data format in ***Direct***Soft, select Signed Decimal.

For unipolar thermocouple ranges (R,S,B,C), it does not matter if magnitude plus sign or 2's complement is selected.

Use the table to select settings. The module comes with both jumpers installed for magnitude plus sign conversion in Fahrenheit. For example, remove the Units-0 jumper and leave the Units-1 jumper installed for magnitude plus sign conversion in Celsius.

X = Jumper installed, and

blank space = Jumper removed.

Number of Channels	Temperature Conversion Units			
	Magnitude + Sign °F	°C	2's Compliment °F	°C
Units-0	X	–	X	–
Units-1	X	X	–	–

Voltage Conversion Units

The bipolar voltage input ranges, 5V or 156mV (see previous page for 5V and 156mV settings), may be converted to a 15-bit magnitude plus sign or a 16-bit 2's complement value.

Use the table to select settings. The module comes with both jumpers installed for magnitude plus sign conversion. Remove the **Units-1** jumper and leave the **Units-0** jumper installed for 2's complement conversion.

X = Jumper installed, and
blank space = Jumper removed.

Jumper Pins	Voltage Conversion Units	
	Magnitude Plus Sign	2's Compliment
Units-0	X	X
Units-1	X	–

NOTE: *When selecting a Unipolar Voltage mode (0-5V, 0-156mV), BCD data type will not give a correct reading. Decimal data type should always be used for Unipolar Voltage modes.*

Connecting the Field Wiring

Wiring Guidelines

Your company may have guidelines for wiring and cable installation. If so, check the guidelines before beginning 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 F2-04THM module requires at least one field-side power supply. The same or separate power sources can be used for the 0–5 V or 0–156 mV transmitter voltage supply. The module requires 10–30 VDC, at 40mA, from the external power supply.

The DL205 AC bases have a built-in 24VDC power supply that provide up to 300mA of current. This can be used instead of a separate supply. 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 internal 24VDC power budget is exceeded, it may cause unpredictable system operation that can lead to a risk of personal injury or equipment damage.

The DL205 base has a switching type power supply. As a result of switching, noise may cause some instability into the analog input data if the base power supply is used. If this is unacceptable, try 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 "G" on the base.

Unused temperature inputs should be shorted together and connected to common.

Thermocouples

Use shielded thermocouples whenever possible to minimize the presence of noise on the thermocouple wire. Ground the shield wire at one end only. For grounded thermocouples, connect the shield at the sensor end. For ungrounded thermocouples, connect the shield to the 0V (common) terminal.

Grounded Thermocouple Assembly

A grounded thermocouple provides better response time than an ungrounded thermocouple because the tip of the thermocouple junction is in direct contact with the protective case.

Ungrounded Thermocouple Assembly

An ungrounded thermocouple is electrically isolated from the protective case. If the case is electrically grounded it provides a low-impedance path for electrical noise to travel. The ungrounded thermocouple provides a more stable and accurate measurement in a noisy environment.

Exposed Grounded Thermocouple

The thermocouple does not have a protective case and is directly connected to a device with a higher potential. Grounding the thermocouple assures that the thermocouple remains within the common mode specifications. Because a thermocouple is essentially a wire, it provides a low-impedance path for electrical noise. The noise filter has a response of >100dB @ 50/60 Hz.

WARNING: A thermocouple can become shorted to a high voltage potential. Because common terminals are internally connected together, whatever voltage potential exists on one thermocouple will exist on the other channels.

Ambient Variations in Temperature

The F2-04THM module has been designed to operate within the ambient temperature range of 0 to 60°C.

The cold junction compensation is calibrated to operate in a still-air environment. If the module is used in an application that has forced convection cooling, an error of 2 to 3°C may be introduced. To compensate for this, ladder logic can be used to correct the values.

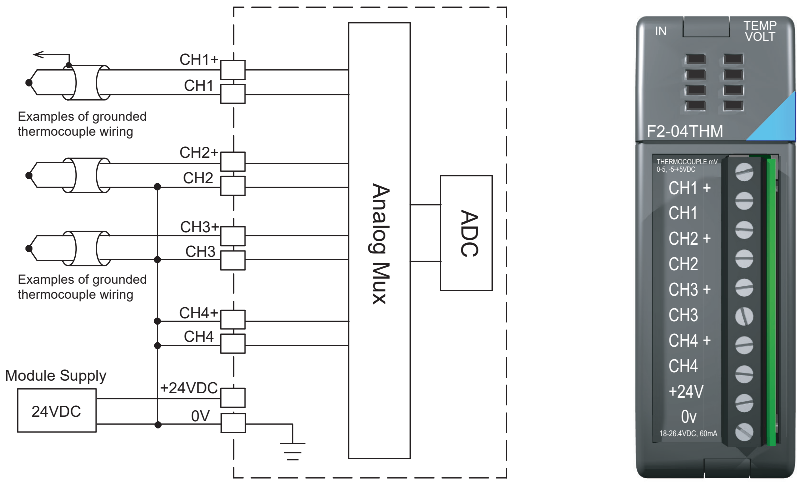
When configuring the system design it is best to locate any heat-producing devices above and away from the PLC chassis because the heat will affect the temperature readings. For example, heat introduced at one end of the terminal block can cause a channel-to-channel variation.

When exposing the F2-04THM module to abrupt ambient temperature changes it will take several minutes for the cold junction compensation and terminal block to stabilize. Errors introduced by abrupt ambient temperature changes will be less than 4°C.

Wiring Diagrams

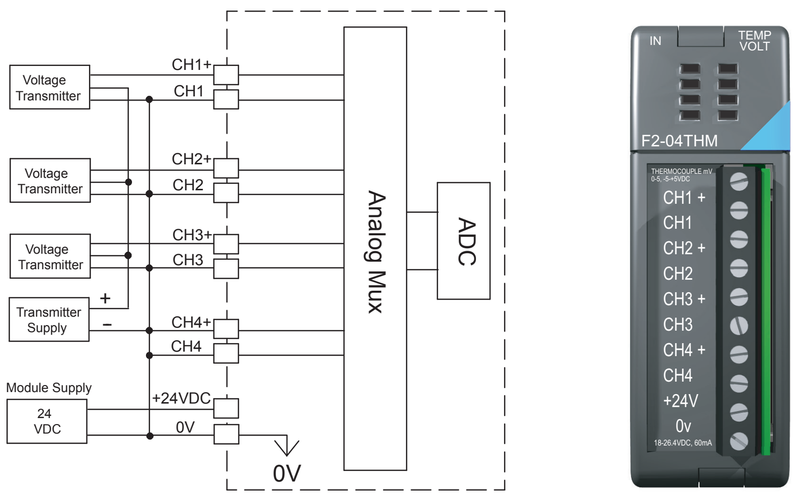
Use the following diagrams to connect the field wiring.

Thermocouple Input Wiring Diagram



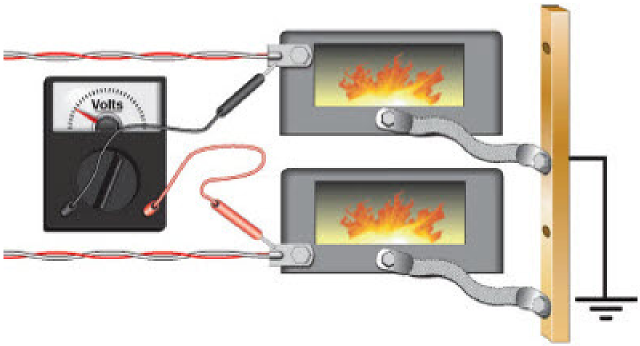
NOTE: *Terminate shields at the respective signal source. Also, connect unused channels to a common terminal (0V, CH4+, CH4).*

Voltage Input Wiring Diagram



NOTE: *Connect unused channels to a common terminal (0V, CH4+, CH4). Also, when using 0-156 mV and 5V ranges, connect (-) or 0V terminals (CH1, CH2, CH3, CH4) to 0V module supply terminal to ensure common mode acceptance.*

With grounded thermocouples, take precautions to prevent having a voltage potential between thermocouple tips. A voltage of 1.25V or greater between tips will skew measurements.

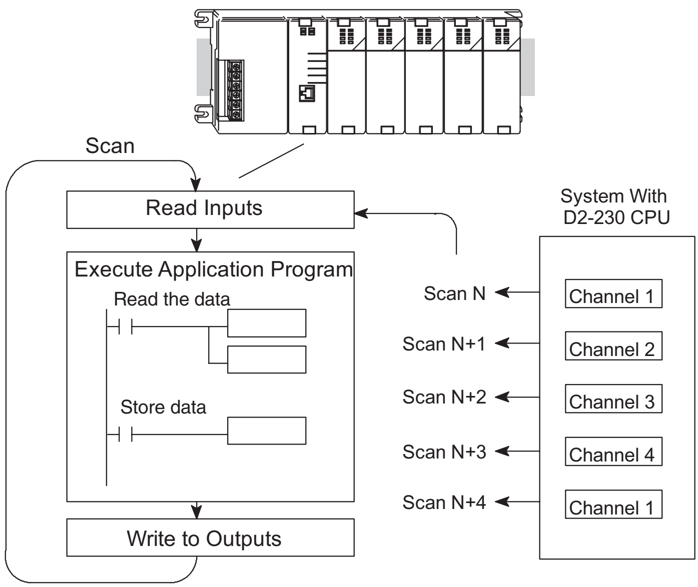


Module Operation

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

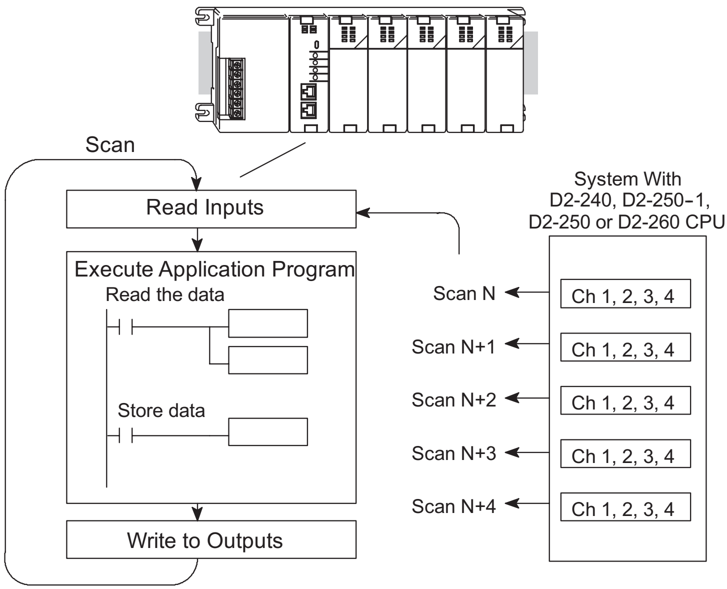
Channel Scanning Sequence (Multiplexing) for a D2-230 CPU

The F2-04THM module can supply different amounts of data per scan, depending on the type of CPU being used. The D2-230 can obtain one channel of data per CPU scan. Since there are four channels, it can take up to four 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 D2-240, D2-250-1, D2-260 or D2-262 CPUs.



Channel Scanning Sequence (Pointer Method) for D2-240, D2-250-1, D2-260 and D2-262 CPUs

If a D2-240, a D2-250-1, a D2-260 or a D2-262 CPU is being used, all four channels of input data can be captured in one scan. This is because the D2-240, D2-250-1, D2-260 and D2-262 CPUs support special V-memory locations that are used to manage the data transfer. This is discussed in more detail in the next 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 16-bit binary representation. This enables the module to continuously provide accurate measurements without slowing down the discrete control logic in the RLL program.

The time required to sense the temperature and copy the value to V-memory is 1.4 seconds for a single board design module (5.4 seconds for a two board design module) plus 1 scan time maximum.

Writing the Control Program

Reading Values Pointer Method and Multiplexing

There are two methods of reading values:

- Pointer method
- Multiplexing

The multiplexing method must be used with a D2-230 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 D2-240, D2-250-1, D2-260 and D2-262 CPUs, but for ease of programming it is highly recommended to use the pointer method.

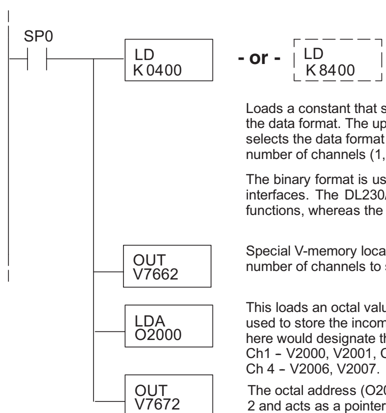
Pointer Method for the D2-240, D2-250-1, D2-260 and D2-262 CPUs

The CPU has special V-memory locations (shown in tables on the following page) assigned to each base slot that greatly simplifies 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

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 used. This is all that is required to read the data into V-memory locations. Once the data is in V-memory, math instructions can be used on the data, compare the data against preset values, etc. V2000 is used in the example, but any user V-memory location can be used. The module is installed in slot 2 for the examples. Use the V-memory locations shown in the application. The pointer method automatically converts values to BCD.

NOTE: *D2-240 CPUs with firmware release version 2.5 or later and D2-250 CPUs with firmware release version 1.06 or later support this method. Use the D2-230 multiplexing example if the firmware revision is earlier.*



Loads a constant that specifies the number of channels to scan and the data format. The upper byte, most significant nibble (MSN) selects the data format (0=BCD, 8=Binary), the LSN selects the number of channels (1, 2, 3, or 4).

The binary format is used for displaying data on some operator interfaces. The DL230/240 CPUs do not support binary math functions, whereas the DL250 does.

Special V-memory location assigned to slot 2 that contains the number of channels to scan.

This loads an octal value for the first V-memory location that will be used to store the incoming data. For example, the O2000 entered here would designate the following addresses:
Ch1 – V2000, V2001, Ch 2 – V2002, V2003, Ch 3 – V2004, V2005, Ch 4 – V2006, V2007.

The octal address (O2000) is stored here. V7672 is assigned to slot 2 and acts as a pointer, which means the CPU will use the octal value in this location to determine exactly where to store the incoming data.

The following tables show the special V-memory locations used by the D2-240, D2-250-1, D2-260 and D2-262 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 the D2-230 (multiplexing) method is used, verify that these addresses in the CPU are 0 (zero).

The Table below applies to the D2-240, D2-250-1, D2-260 and D2-262 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 D2-250-1, D2-260 and D2-262 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 D2-250-1, D2-260 and D2-262 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	V36104	V36105	V36106	V36107
Storage Pointer	V36110	V36111	V36112	V36113	V36114	V36115	V36116	V36117

The Table below applies to the D2-260 and D2-262 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 D2-260 and D2-262 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

Negative Temperature Readings with Magnitude Plus Sign (Pointer Method) for D2-240, D2-250-1, D2-260 and D2-262 CPUs

With bipolar ranges, some additional logic will be needed to determine whether the value being returned represents a positive voltage or a negative voltage. For example, the direction for a motor might need to be known. There is a solution for this:

- If bipolar ranges are used and a value greater than or equal to 8000_{hex} is obtained, the value is negative.
- If a value less than or equal to $7FFF_{hex}$ is obtained, then the value is positive.

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

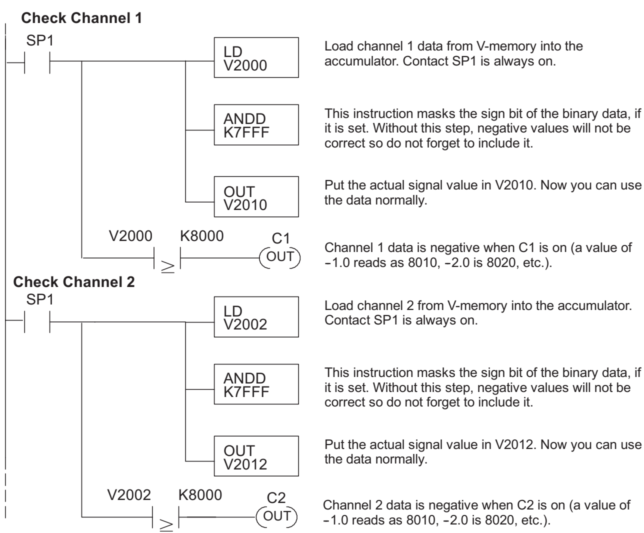
NOTE: *D2-240 CPUs with firmware release version 2.5 or later and D2-250 CPUs with firmware release version 1.06 or later support this method. Use the D2-230 multiplexing example if your firmware is an earlier version.*

The following two programs on this page and the next page show how this can be accomplished. The first example uses magnitude plus sign (binary) and the second example uses magnitude plus sign (BCD). The examples only show two channels.

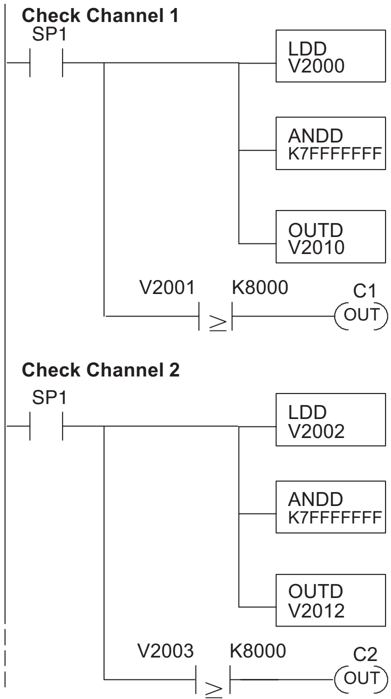
It is good to know when a value is negative, so these rungs should be placed before any other operations that use the data, such as math instructions, scaling operations, etc. Also, if stage programming instructions are being used, these rungs should be in a stage that is always active.

NOTE: *This logic is only needed for each channel that is using bipolar input signals.*

Magnitude Plus Sign (Binary)



Magnitude Plus Sign (BCD)



Load channel 1 data from V-memory into the accumulator. Remember, the data can be negative. Contact SP1 is always on.

This instruction masks the sign bit of the BCD data, if it is set. Without this step, negative values will not be correct so do not forget to include it.

Put the actual signal value in V2010. Now you can use the data normally.

Channel 1 data is negative when C1 is on (a value of −1.0 reads as 8000 0010, −2.0 is 8000 0020, etc.).

Load channel 2 from V-memory into the accumulator. Remember, the data can be negative. Contact SP1 is always on.

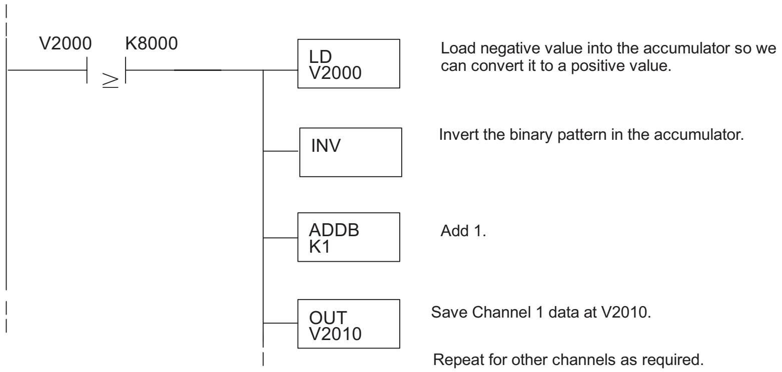
This instruction masks the sign bit of the BCD data, if it is set. Without this step, negative values will not be correct so do not forget to include it.

Put the actual signal value in V2012. Now you can use the data normally.

Channel 2 data is negative when C2 is on (a value of −1.0 reads as 8000 0010, −2.0 is 8000 0020, etc.).

Negative Temperatures 2's Complement (Binary/Pointer Method) for D2-240, D2-250-1, D2-260 and D2-262 CPUs

The 2's complement mode is used for negative temperature display purposes, while at the same time using the magnitude plus sign of the temperature in a control program. The DirectSoft element Signed Decimal is used to display negative numbers in 2's complement form. To find the absolute value of a negative number in 2's complement, invert the number and add 1 as shown in the following example:

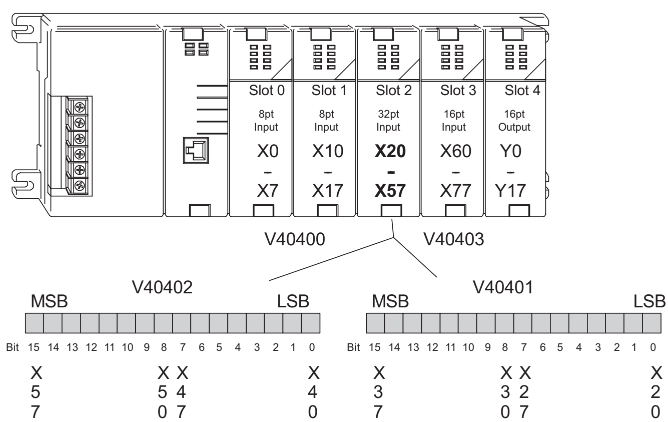


Understanding the Input Assignments (Multiplexing Ladder Only)

Remember that the F2-04THM module appears as a 32-point discrete input module to the CPU. Use these points 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 easy to determine the location of the data word that will be assigned to the module.



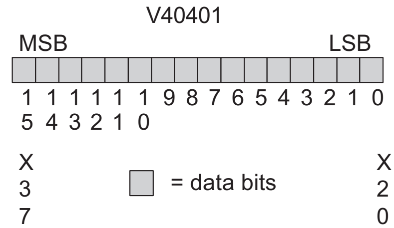
When a D2-230 CPU is used, the input points must start on a V-memory boundary. To use the V-memory references required for a D2-230 CPU, refer to the table below. The first input address assigned to a module must be one of the X inputs shown. The table also shows the V-memory addresses that correspond to these X inputs.

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

Analog Data Bits

The first 16 bits represent the analog data in binary format.

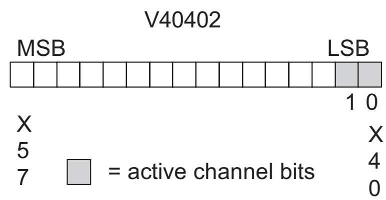
Bit	Value	Bit	Value
0	1	8	256
1	2	9	512
2	4	10	1024
3	8	11	2048
4	16	12	4096
5	32	13	8192
6	64	14	16384
7	128	15	32768



Active Channel Bits

The active channel bits represent the multiplexed channel selections in binary format.

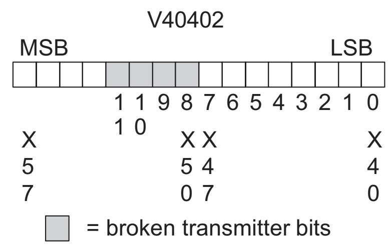
Bit 1	Bit 0	Channel
0	0	1
0	1	2
1	0	3
1	1	4



Broken Transmitter Bits (Pointer and Multiplexing Ladder Methods)

The broken transmitter bits are on when the corresponding RTD is open.

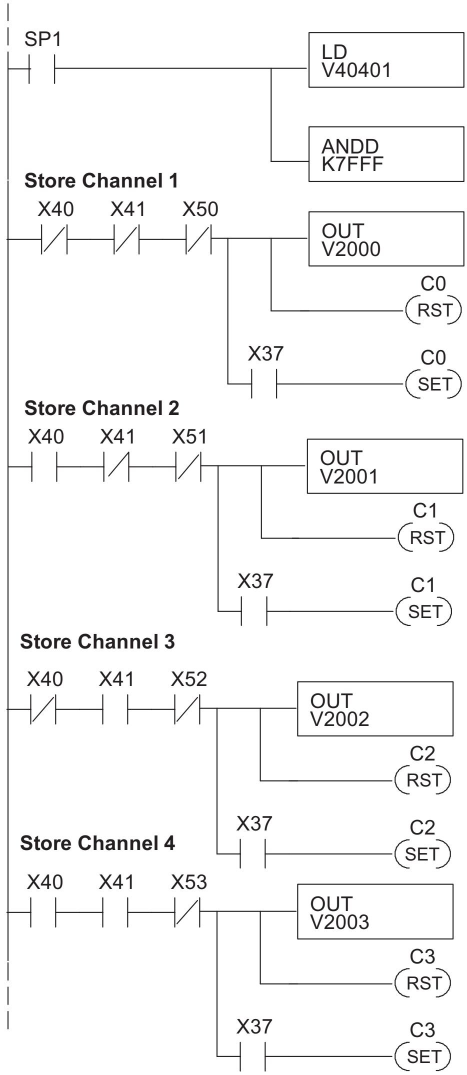
Bit	Channel
8	1
9	2
10	3
11	4



Reading Magnitude Plus Sign Values (Multiplexing)

The D2-230 CPU does not have the special V-memory locations that allows for automatic management of the data transfer. Since all channels are multiplexed into a single data word, the control program must be set up 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: *D2-230 CPUs with firmware release version 1.6 or later required for multiplexing ladder.*



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 sign bit. Without this, the values used will not be correct so do not forget to include it.

When X40, X41, and X50 are off, channel 1 data is stored in V2000. C0 is reset to indicate that channel 1’s value is positive.

If X37 is on, the data value represents a negative temperature. C0 is set to indicate that channel 1’s value is negative.

When X40 is on and X41 and X51 are off, channel 2 data is stored in V2001. C1 is reset to indicate that channel 2’s value is positive.

If X37 is on, the data value represents a negative temperature. C1 is set to indicate that channel 2’s value is negative.

When X40 and X52 are off and X41 is on, channel 3 data is stored in V2002. C2 is reset to indicate that channel 3’s value is positive.

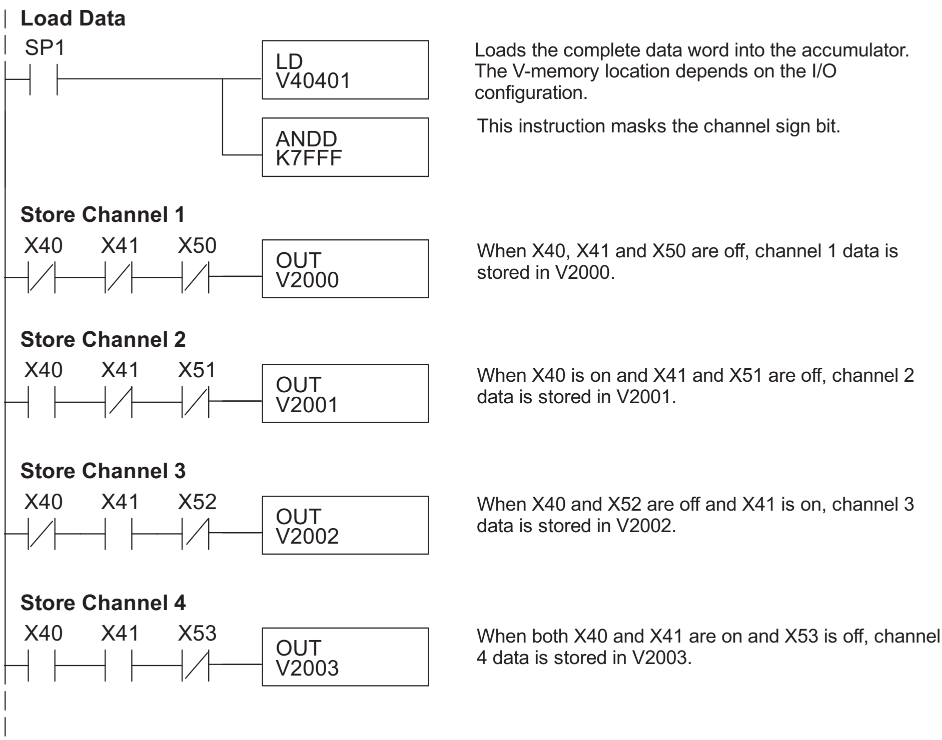
If X37 is on, then the data value represents a negative temperature. C2 is set to indicate that channel 3’s value is negative.

When both X40 and X41 are on and X53 is off, channel 4 data is stored in V2003. C3 is reset to indicate that channel 4’s value is positive.

If X37 is on, the data value represents a negative temperature. C3 is set to indicate that channel 4’s value is negative.

Reading 2's Compliment Values (Multiplexing)

The D2-230 CPU does not have the special V-memory locations that allows for automatic management of the data transfer. Since all channels are multiplexed into a single data word, the control program must be set up 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. The 2's complement data format may be required to correctly display bipolar data on some operator interfaces. This data format could also be used to simplify averaging a bipolar signal. To view this data format in ***Direct***SOFT, select Signed Decimal.



Scaling the Input Data

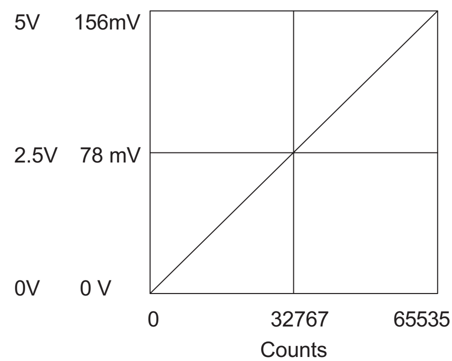
No scaling of the input temperature is required. The readings directly reflect the actual temperatures. For example: a reading of 8482 is 848.2°C, a reading of 16386 is -0.2°C (magnitude plus sign) and a reading of 32770 is -0.2°C (2's complement).

Module Resolution 16-Bit (Unipolar Voltage Input)

Unipolar analog signals are converted into 65536 counts ranging from 0–65535 (2^{16}). For example, with a 0–156mV signal range, 78mV would be 32767. A value of 65535 represents the upper limit of the range.

H or L = high or low limit of the range

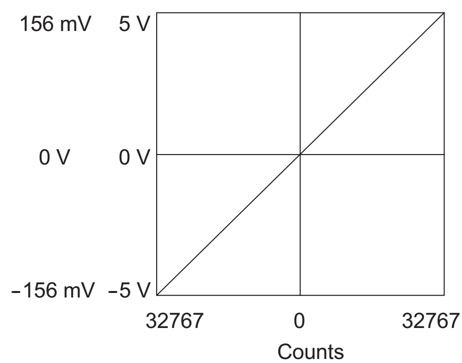
$$\text{Unipolar Resolution} = \frac{H - L}{65535}$$



Module Resolution 15-Bit Plus Sign(Bipolar Voltage Input)

The module has 16-bit unipolar or 15-bit + sign bipolar resolution. Bipolar analog signals are converted into 32768 counts ranging from 0–32767 (2^{15}). For example, with a -156mV–156mV signal range, 156mV would be 32767. The bipolar ranges utilize a sign bit to provide 16-bit resolution. A value of 32767 can represent the upper limit of either side of the range. Use the sign bit to determine negative values.

H or L = high or low limit of the range



$$\text{Bipolar Resolution} = \frac{H - L}{32767}$$

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 startup or troubleshooting. This module does not operate like other versions of analog input modules. The bipolar ranges use 0–32767 for both positive and negative voltages. The sign bit allows this and it 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.
0–5 V	$A = \frac{5D}{65535}$	$D = \frac{65535}{5}(A)$
0–156.25 mV	$A = \frac{0.15625D}{65535}$	$D = \frac{65535}{0.15625}(A)$
±5V	$A = \frac{10D}{65535}$	$D = \frac{65535}{10}(A)$
±156.25 mV	$A = \frac{0.3125D}{65535}$	$D = \frac{65535}{0.3125}(A)$

For example, if the ±5V range is used and the signal is measured at 2.5V, use the following formula to determine the digital value that is stored in the V-memory location that contains the data.

$$D = \frac{65535}{10}(A)$$

$$D = \frac{65535}{10}(2.5V)$$

$$D = 6553.5\ (2.5)$$

$$D = 16383.75$$

Filtering Input Noise (D2-250-1, D2-260 and D2-262 CPUs Only)

Add the following logic to filter and smooth analog input noise in D2-250-1, D2-260 and D2-262 CPUs. This is especially useful when using PID loops. Noise can be generated by the field device and/or induced by field wiring.

In the following example, the analog value in BCD is first converted to a binary number. Memory location V1400 is the designated workspace in this example. The MULR instruction is the filter factor, which can be from 0.1–0.9. The example uses 0.2. Using 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 the application program or a PID loop.

NOTE: *Please review intelligent instructions (IBox) in Chapter 5, which simplify this and other functions. The IBox instructions are supported by the D2-250-1, D2-260 and D2-262.*

NOTE: *Be careful not to do a multiple number conversion on a value. For example, if the pointer method is used to get the analog value, it is in BCD and must be converted to binary. However, if the conventional method of reading analog is used and the first 15 bits are masked, the value is already in binary and no conversion is needed. Also, if the conventional method is used, change the LDD V2000 instruction to LD V2000.*