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F3–08THM–n 8-Channel Thermocouple Input

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Introduction

Automatic Conversion

The F3–08THM–n Thermocouple Input Module provides eight, differential thermocouple input channels (12-bit resolution). The module automatically converts type E, J, K, R, S or T thermocouple signals into direct temperature readings. No extra scaling or complex conversion is required. You can select between °F or °C operation.

This module is also available in versions specially designed to convert millivolt signal levels into direct digital values (0–4095). Two versions are available, one for 0–50mV and one for 0–100mV.

Hardware Features

The F3–08THM–n also features automatic cold junction compensation, thermocouple linearization, plus analog and digital filtering. The temperature calculation and linerazation are based on data provided by the National Bureau of Standards.

Diagnostic Features

Thermocouple burnout and other errors are automatically reported to the CPU. For example, if the thermocouple becomes disconnected, then a value of 4095 is assigned to that channel.

Module Specifications

The following table provides the specifications for the F3–08THM–n Thermocouple Input Module from FACTS Engineering. Review these specifications to make sure the module meets your application requirements.

Number of Channels	8, differential inputs
Input Ranges	Type E: –270/1000 °C, –450/1832 °F Type J: –210/760 °C, –350/1390 °F Type K: –270/1370 °C, –450/2500 °F Type R: 0/1768 °C, –32/3214 °F Type S: 0/1768 °C, –32/3214 °F Type T: –270/400 °C, –450/752 °F –1: 0 – 50 mV –2: 0–100 mV
Resolution	12 bit (1 in 4096)
Input Impedance	27KΩ DC
Absolute Maximum Ratings	Fault protected input, 130 Vrms or 100 VDC
Cold Junction Compensation	Automatic
Conversion Time	15ms per channel, minimum 1 channel per CPU scan
Converter Type	Successive Approximation, 574
Linearity Error	±1 count (0.03% of full scale) maximum
Maximum Inaccuracy at 77 °F (25 °C)	0.35% of full scale
Accuracy vs. Temperature	57 ppm / °C maximum full scale
Power Budget Requirement	50 mA @ 9 VDC, 34 mA @ 24 VDC
External Power Supply	None required
Operating Temperature	32° to 140° F (0° to 60° C)
Storage Temperature	–4° to 158° F (–20° to 70° C)
Relative Humidity	5 to 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

Analog Input Configuration Requirements

The F3–08THM–n Thermocouple Input appears as a 16-point module. The module can be installed in any slot configured for 16 points. See the DL305 User Manual for details on using 16 point modules in DL305 systems. The limitation on the number of analog modules are:

- For local and expansion systems, the available power budget and 16-point module usage are the limiting factors.

Setting the Module Jumpers

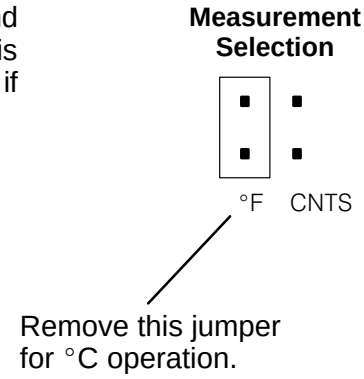
Jumper Locations

The module is set at the factory for °C thermocouple readings. If this is acceptable you do not have to change any of the jumpers. The following diagram shows how the jumpers are set.

WARNING: DO NOT change the calibration jumper settings. If you think this jumper has been changed, make sure it is NOT in the CAL position. All calibration is performed at the factory. Any changes to this may affect the module accuracy which could result in the risk of personal injury and/or equipment damage.

Selecting °F or °C Operation

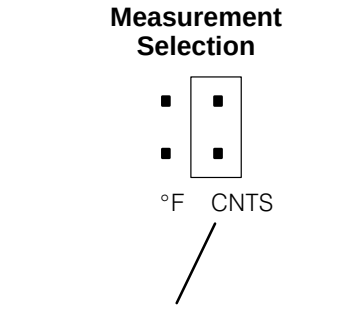
There is a jumper located on the bottom of the board that selects between °C and °F temperature measurements. This jumper (labeled °F) should be removed if you require °C measurements.



Selecting 0–4095 Operation

There is a jumper located on the bottom of the board that allows you to disable the direct temperature conversion feature. If you install a jumper on the CNTS pin, the temperature will be represented by a digital value between 0 and 4095. For example, an E type thermocouple would have a value of 0 for –450 °F and a value of 4095 for 1832 °F.

NOTE: If you are using the –1 (50mV) or the –2 (100mV) millivolt input versions, you should make sure this jumper is installed.



Connecting the Field Wiring

Wiring Guidelines

Your company may have guidelines for wiring and cable installation. If so, you should check those before you begin the installation. Here are some general things to consider.

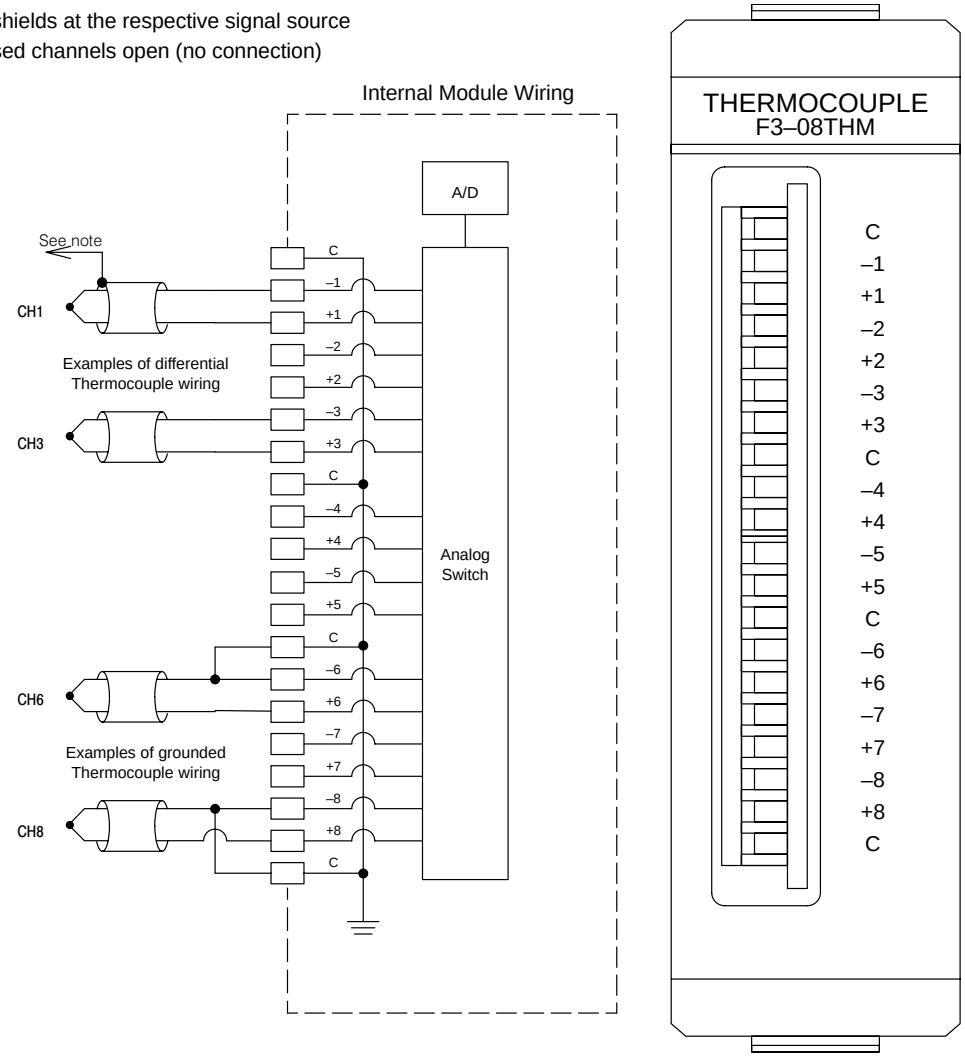
- Use the shortest wiring route whenever possible.
- Use shielded wiring and ground the shield at the signal source. *Do not* ground the shield at both the module and the source.
- Don't run the signal wiring next to large motors, high current switches, or transformers. This may cause noise problems.
- 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 F3–08THM–n receives all power from the base. A separate power supply is not required.

Wiring Diagram

Note 1: Terminate shields at the respective signal source
Note 2: Leave unused channels open (no connection)

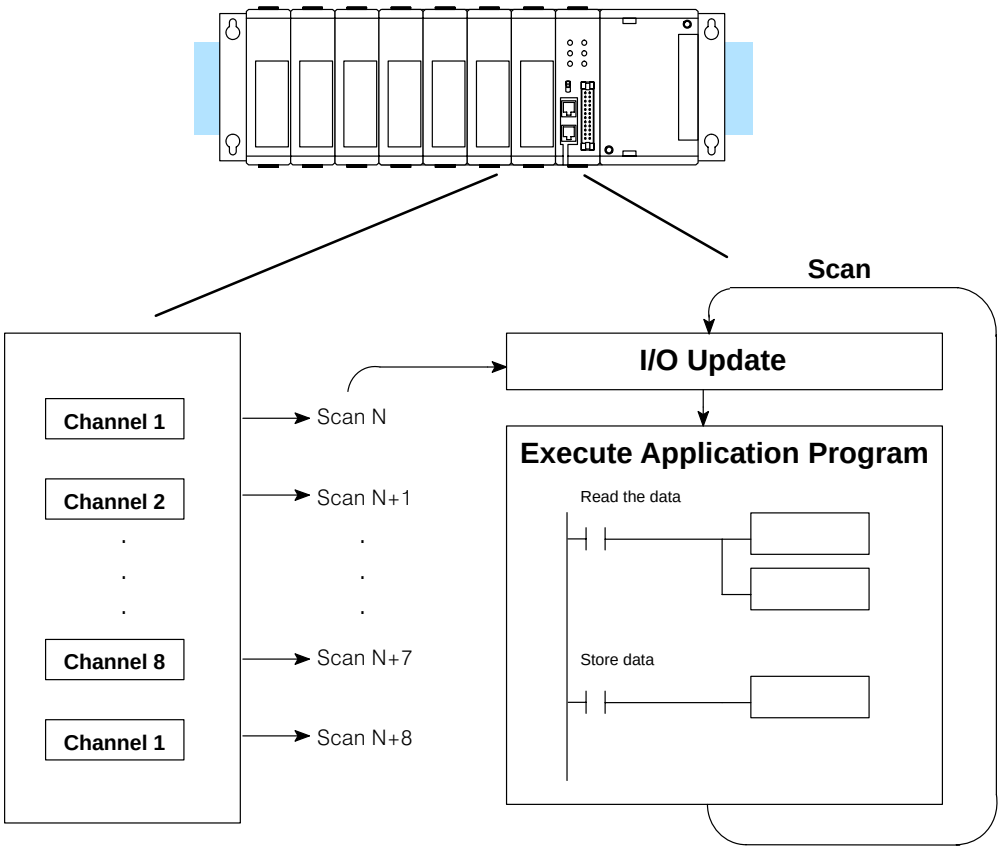


Module Operation

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

Channel Scanning Sequence

The F3–08THM–n module supplies1 channel of data per each 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.



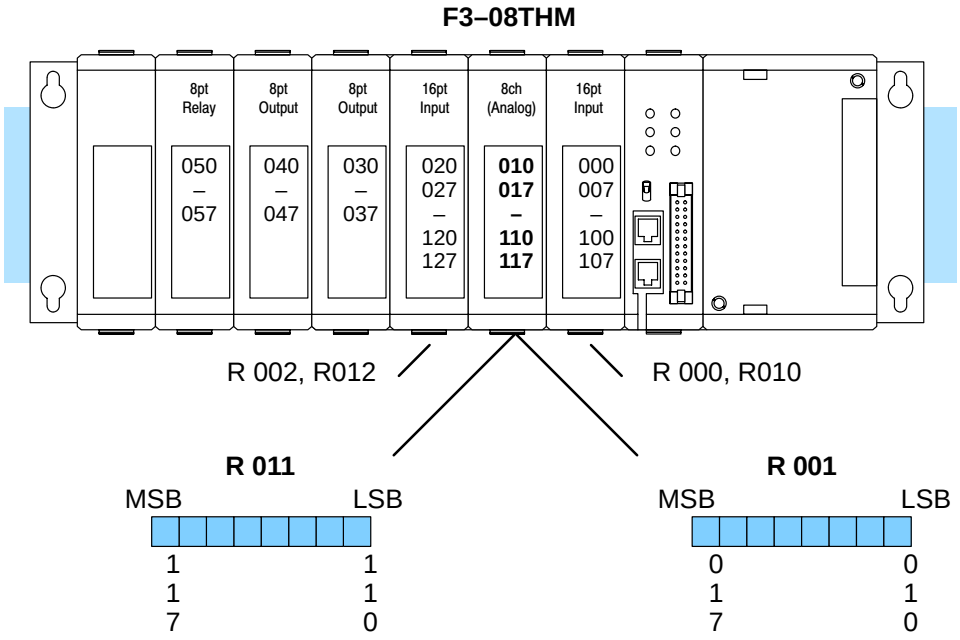
Even though the channel updates to the CPU are synchronous with the CPU scan, the module asynchronously monitors the thermocouple signal and converts the signal to a temperature (or 12-bit binary) representation. This enables the module to continuously provide accurate measurements without slowing down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

Understanding the I/O Assignments

You may recall the F3–08THM–n module appears to the CPU as a 16-point module. These 16 points provide:

- an indication of which channel is active.
- the digital representation of the temperature.

Since all I/O points are automatically mapped into Register (R) memory, it is very easy to determine the location of the data word that will be assigned to the module.

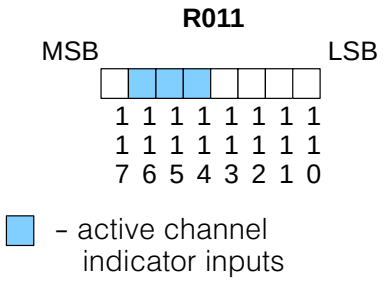


Within these two register locations, the individual bits represent specific information about the analog signal.

Active Channel Indicator Inputs

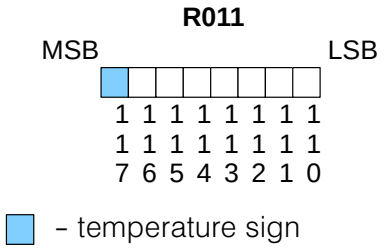
The next to last three bits of the upper Register indicate the active channel. The indicators automatically increment with each CPU scan.

Scan	Active Channel Inputs	Channel
N	000	1
N+1	001	2
N+2	010	3
N+3	011	4
N+4	100	5
N+5	101	6
N+6	110	7
N+7	111	8
N+8	000	1



Temperature Sign Bit

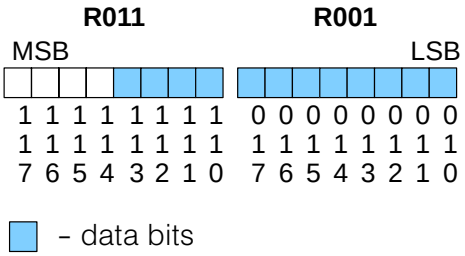
The most significant bit is used to note the sign of the temperature. If this bit is on, then the temperature is negative. If the bit is off, then the temperature is positive.



Analog Data Bits

The first twelve bits represent the temperature. If you have selected the 0–4095 scale, the following format is used.

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



Temperature Input Resolution

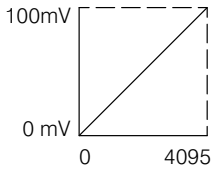
Typically, the F3–08THM–n resolution enables you to detect a 1 °C change in temperature. The National Bureau of Standards publishes conversion tables that show how each temperature corresponds to an equivalent signal level.

Millivolt Input Resolution

Since the module has 12-bit resolution, the analog signal is converted into 4096 "pieces" ranging from 0 – 4095 (2^{12}). For example, with a –2 (100mV) module a signal of 0 mV would be 0, and a signal of 100 mV would be 4095. This is equivalent to a a binary value of 0000 0000 0000 to 1111 1111 1111, or 000 to FFF hexadecimal. The diagram shows how this relates to the example signal range.

Each "piece" can also be expressed in terms of the signal level by using the equation shown. The following table shows the smallest signal levels that will result in a change in the data value for each signal range.

0–100 mV Scale



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

H = high limit of the signal range

L = low limit of the signal range

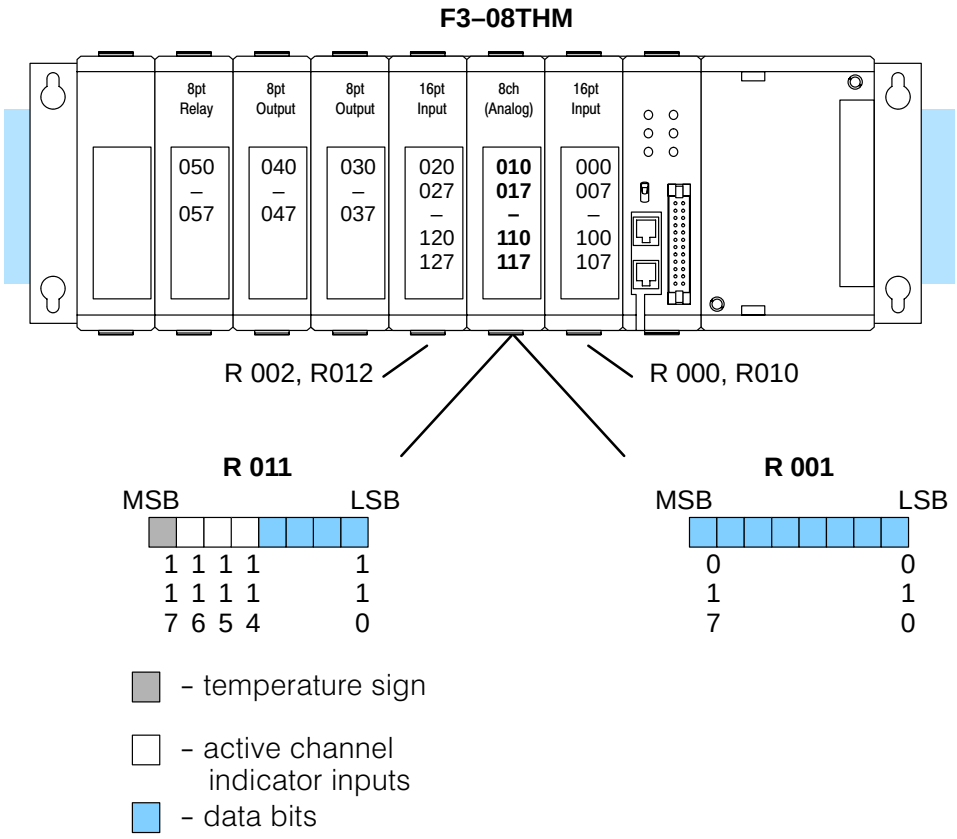
Range	Highest Signal	Lowest Signal	Smallest Change
0 – 50 mV	50 mV	0 mV	12.2 µV
0 – 100 mV	100mA	0mA	24.2 µV

Now that you understand how the module and CPU work together to gather and store the information, you're ready to write the control program.

Writing the Control Program (DL330 / DL340)

Identifying the Data Locations

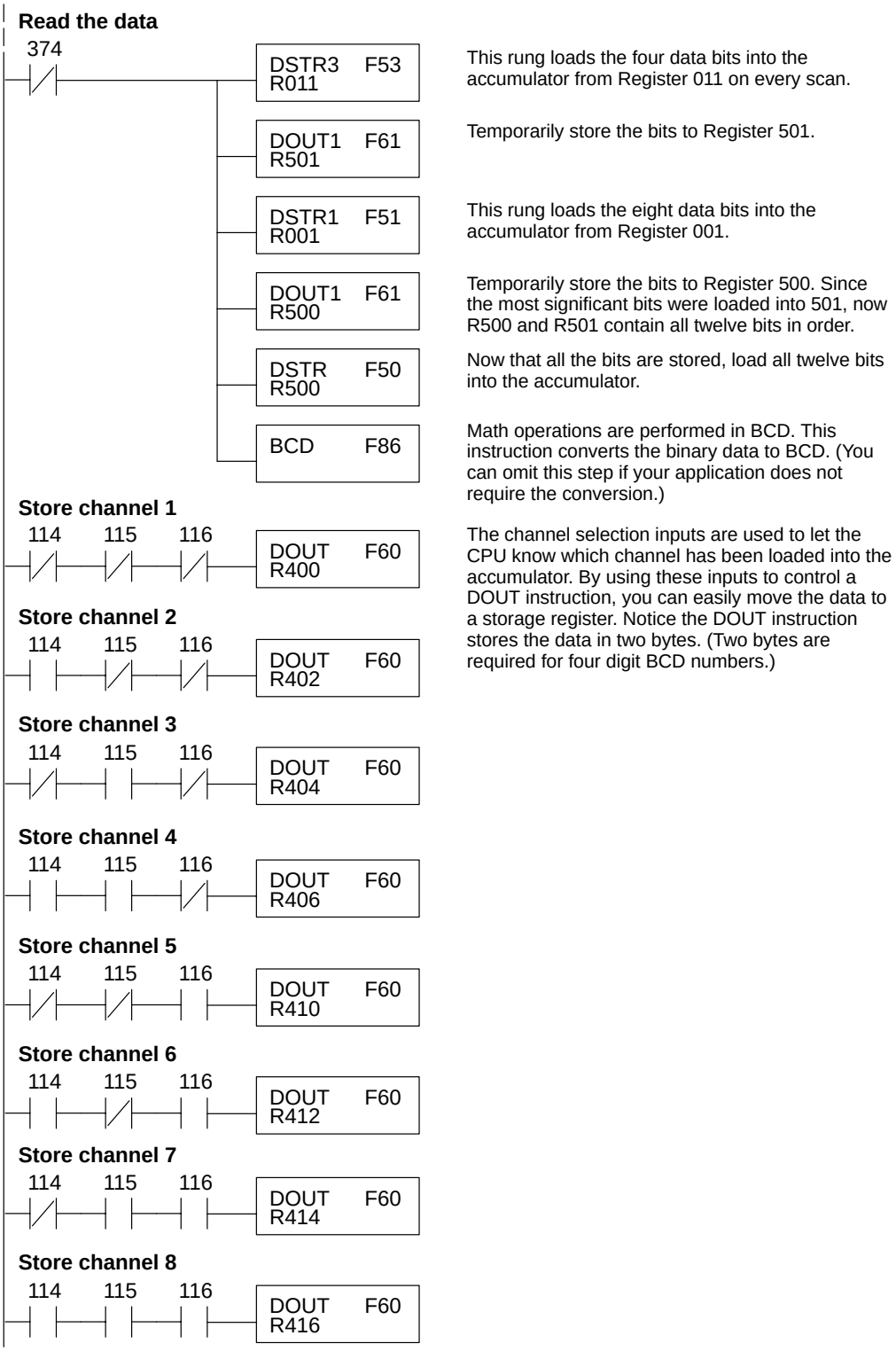
Since all channels are multiplexed into a single data word, the control program must be setup to determine which channel is being read. Since the module provides input points to the CPU, it is very easy to use the channel status bits to determine which channel is being monitored.



Automatic Temperature Conversion

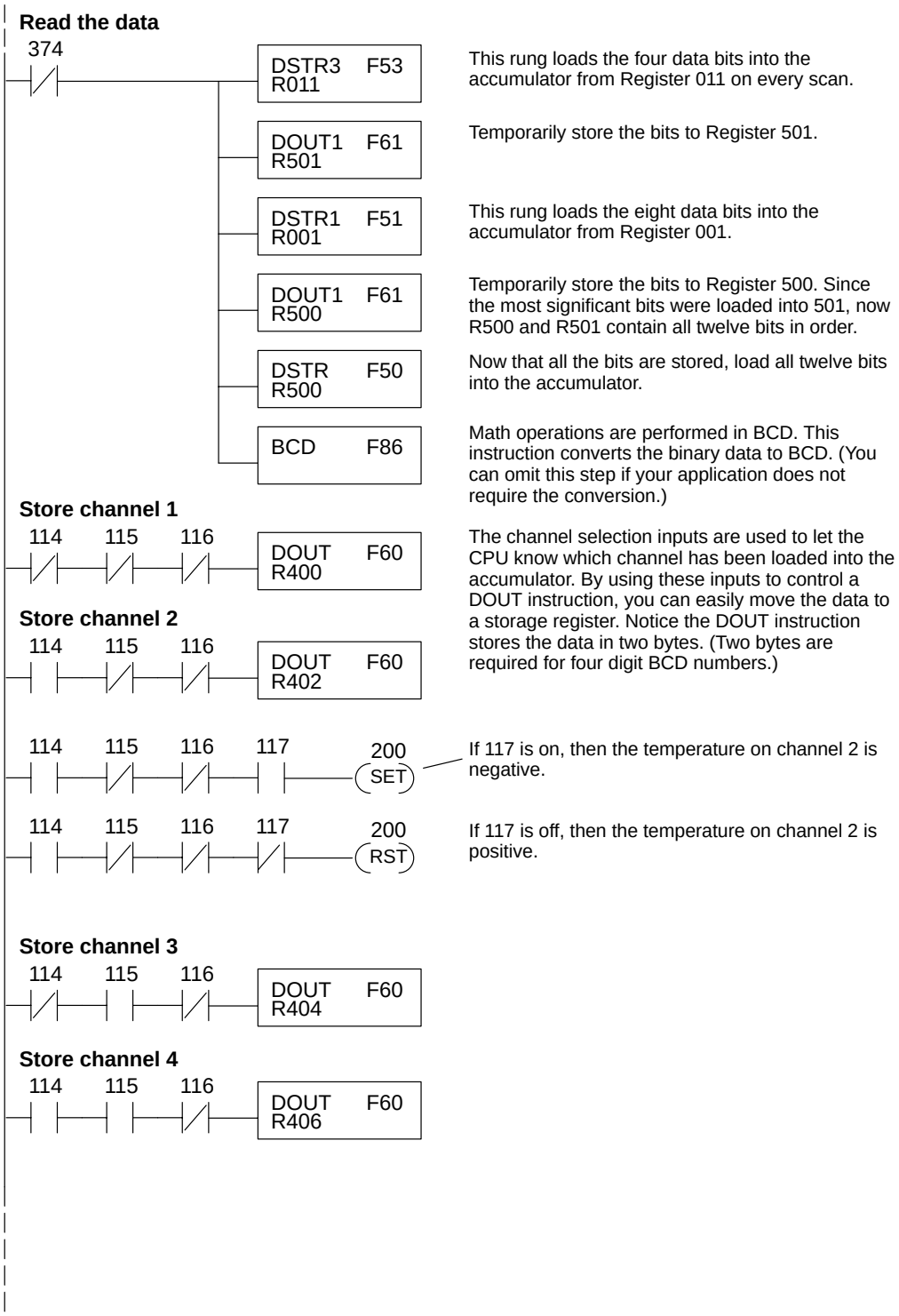
If you are using the temperature scale (°F or° C) then you do not have to perform any scaling. Once you convert the binary temperature reading to a four-digit BCD number, you have the temperature.

The following example shows a program designed to read any of the available channels of data into Register locations. Once the data is in a Register, you can perform math on the data, compare the data against preset values, etc. Since the DL305 CPUs use 8-bit word instructions, you have to move the data in pieces. It's simple if you follow the example.



Using the Sign Bit

By adding a couple of simple rungs you can easily monitor the temperature for positive vs. negative readings. (For example, you have to know whether the temperature is +100 °F or –100 °F.) Notice how we've changed Channel 2 to control an output that denotes the sign of the temperature.



Scaling the Input Data

If you are using the –1 (50mV) or the –2 (100mV) versions, you may want to scale the data to represent the measurements in engineering units, which provide more meaningful data. This is accomplished by using the conversion formula shown.

$$\text{Units} = \frac{A}{4096} S$$

Units = value in Engineering Units

A = Analog value (0 – 4095)

S = high limit of the Engineering unit range

NOTE: The thermocouple versions automatically provide the correct temperature readings. Scaling is not required.

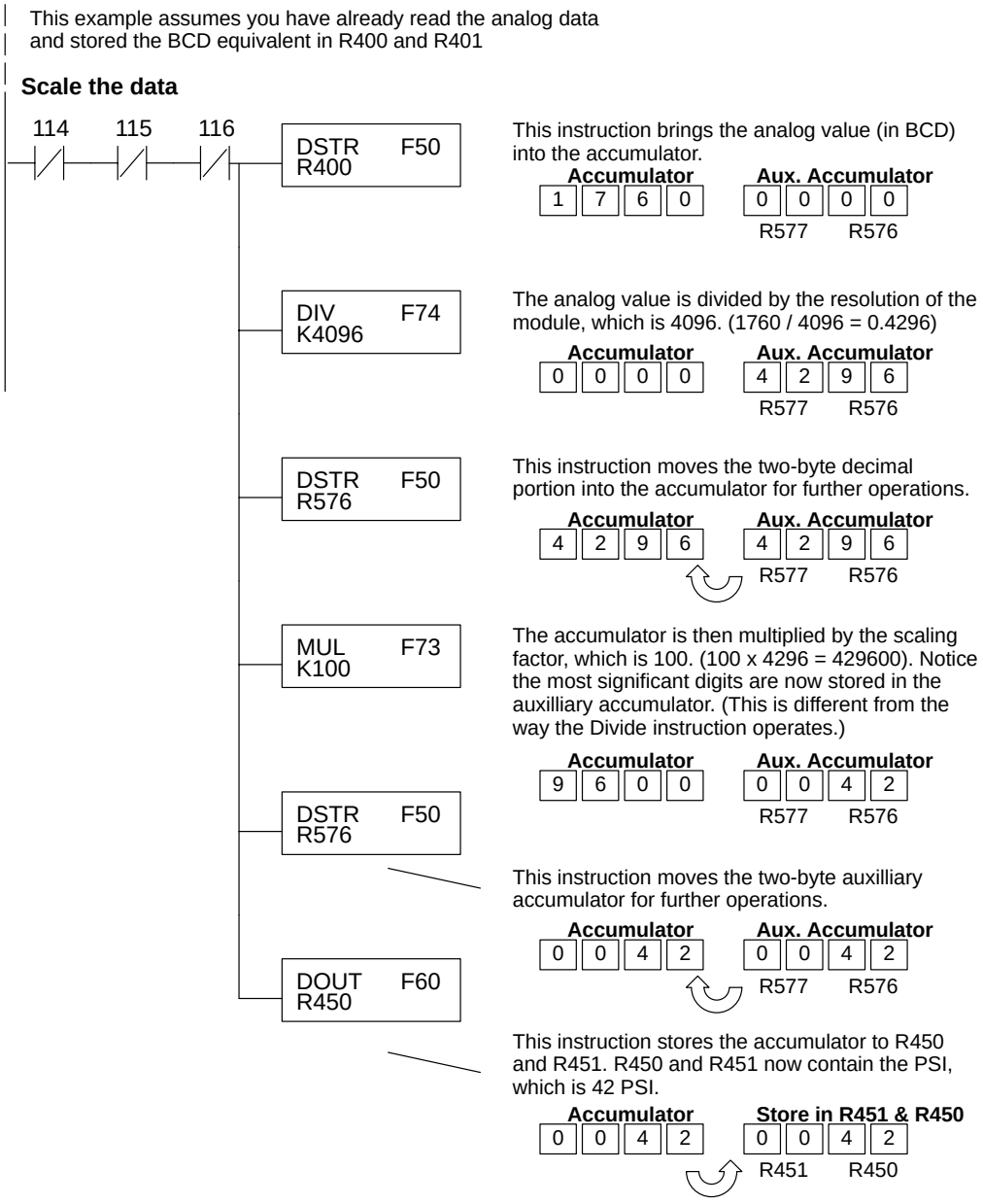
The following example shows how you would use the analog data to represent pressure (PSI) from 0 to 100. This example assumes the analog value is 1760. This should yield approximately 42.9 PSI.

$$\text{Units} = \frac{A}{4096} S$$

$$\text{Units} = \frac{1760}{4096} 100$$

$$\text{Units} = 42.9$$

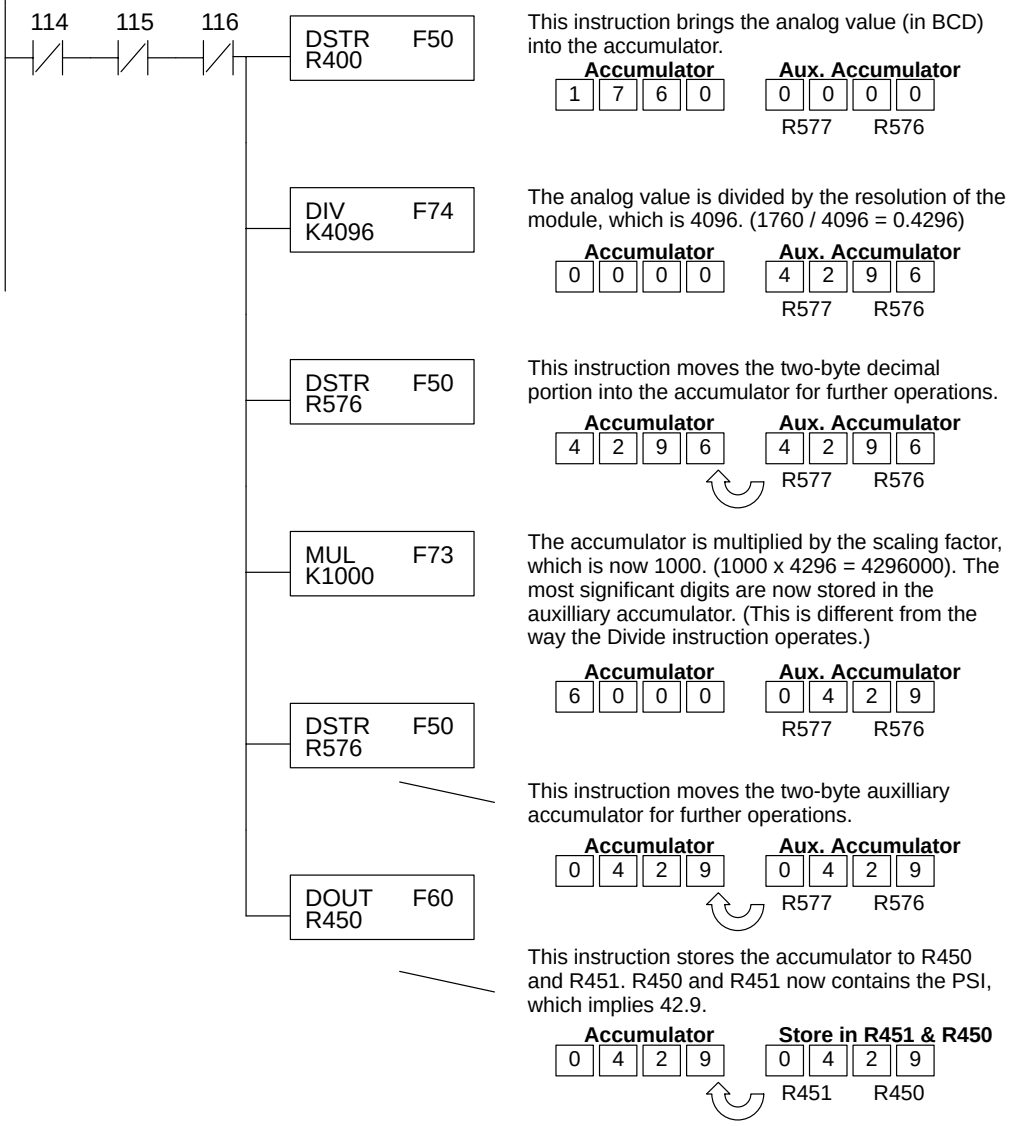
The following instructions are required to scale the data. (We'll continue to use the 42.9 PSI example.) Once we've explained how these instructions operate, we'll show an example program.



You probably noticed the previous example yielded 42 PSI when the real value should have been 42.9 PSI. By changing the scaling value slightly, we can “imply” an extra decimal of precision. Notice in the following example we’ve added another digit to the scale. Instead of a scale of 100, we’re using 1000, which implies 100.0 for the PSI range.

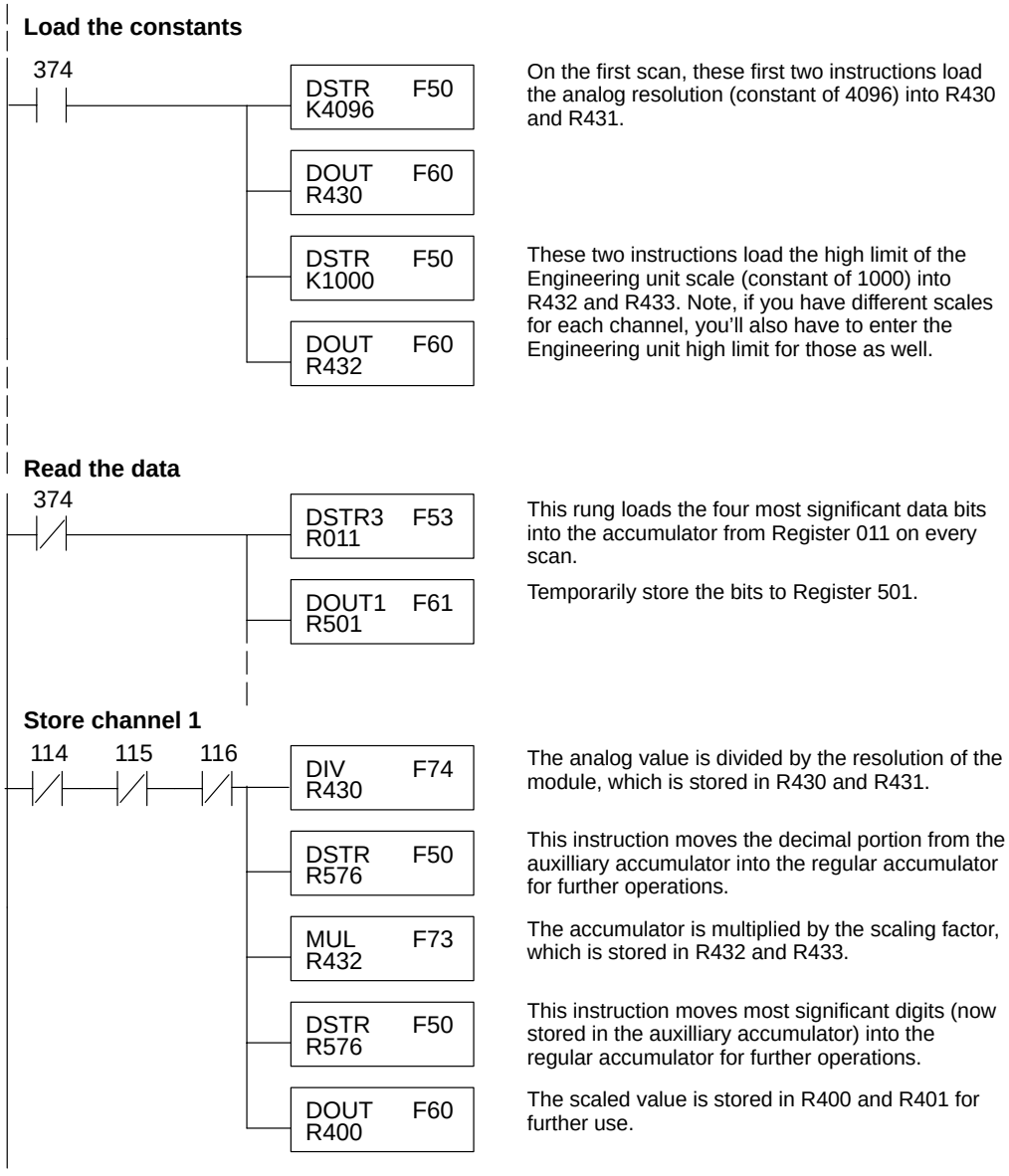
This example assumes you have already read the analog data and stored the BCD equivalent in R400 and R401

Scale the data



This example program shows how you can use the instructions to load these equation constants into data registers. The example is written for channel 1, but you can easily use a similar approach to use different scales for all channels if required.

You may just use the appropriate constants in the instructions dedicated for each channel, but this method allows easier modifications. For example, you could easily use an operator interface or a programming device to change the constants if they are stored in Registers.



On the first scan, these first two instructions load the analog resolution (constant of 4096) into R430 and R431.

These two instructions load the high limit of the Engineering unit scale (constant of 1000) into R432 and R433. Note, if you have different scales for each channel, you'll also have to enter the Engineering unit high limit for those as well.

This rung loads the four most significant data bits into the accumulator from Register 011 on every scan.

Temporarily store the bits to Register 501.

The analog value is divided by the resolution of the module, which is stored in R430 and R431.

This instruction moves the decimal portion from the auxilliary accumulator into the regular accumulator for further operations.

The accumulator is multiplied by the scaling factor, which is stored in R432 and R433.

This instruction moves most significant digits (now stored in the auxilliary accumulator) into the regular accumulator for further operations.

The scaled value is stored in R400 and R401 for further use.

Writing the Control Program (DL350)

Reading Values: Pointer Method and Multiplexing

There are two methods of reading values for the DL350:

- The pointer method **(all system bases must be D3–xx–1 bases to support the pointer method)**
- Multiplexing

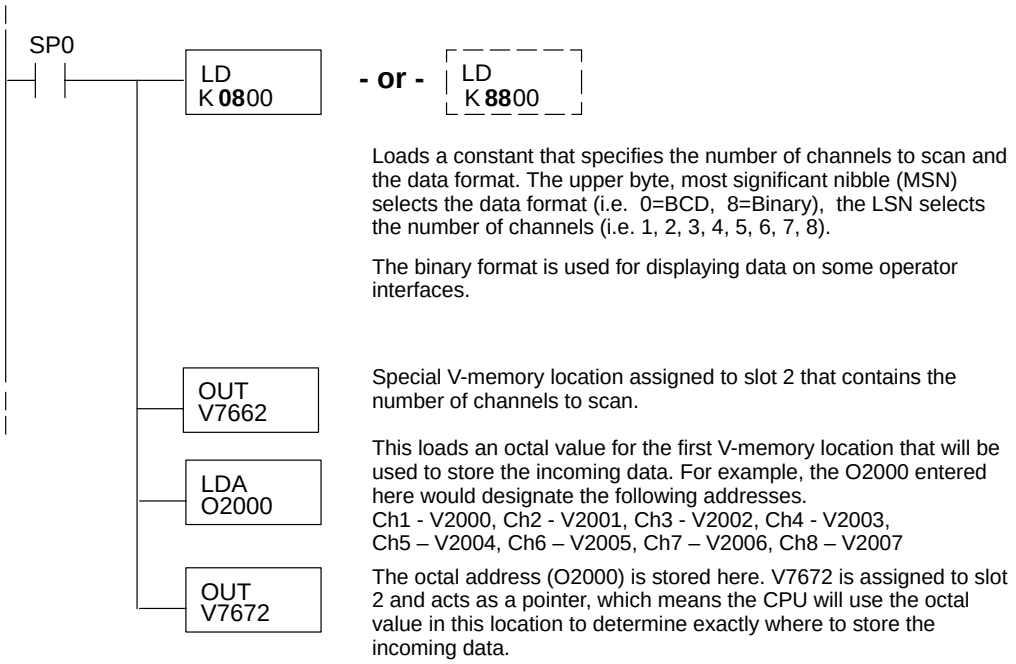
You must use the multiplexing method with remote I/O modules (the pointer method will not work). You can use either method when using DL350, but for ease of programming it is strongly recommended that you use the pointer method.

Pointer Method

The DL350 has special V-memory locations 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 you are using RLL*PLUS* instructions. This is all that is required to read the data into V-memory locations. Once the data is in V-memory, you can perform math on the data, compare the data against preset values, and so forth. V2000 is used in the example, but you can use any user V-memory location. In this example the module is installed in slot 2. You should use the V-memory locations for your module placement.

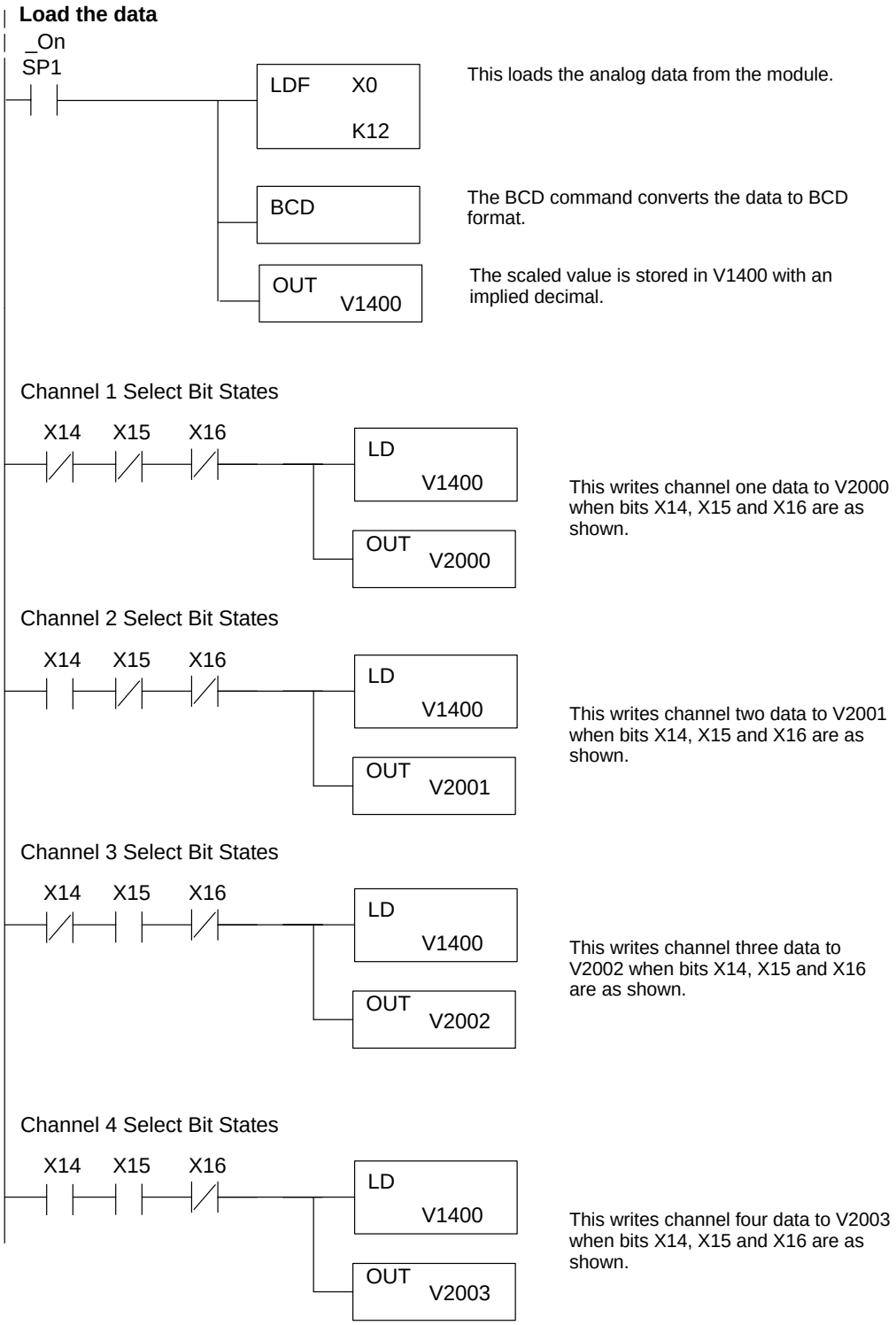


The table shows the special V-memory locations used with the DL350. Slot 0 (zero) is the module next to the CPU, slot 1 is the module two places from the CPU, and so on. Remember, the CPU only examines the pointer values at these locations after a mode transition. The pointer method is supported on expansion bases up to a total of 8 slots away from the DL350 CPU. The pointer method is not supported in slot 8 of a 10 slot base.

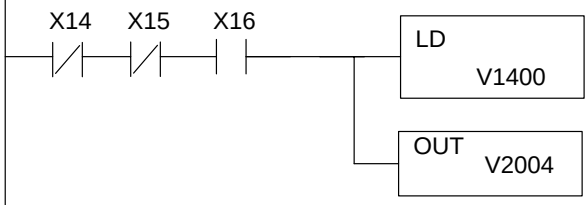
Analog Input Module Slot-Dependent V-memory Locations								
Slot	0	1	2	3	4	5	6	7
No. of Channels	V7660	V7661	V7662	V7663	V7664	V7665	V7666	V7667
Storage Pointer	V7670	V7671	V7672	V7673	V7674	V7675	V7676	V7677

Multiplexing: DL350 with a D3–XX–1 Base

The example below shows how to read multiple channels on an F3–08THM Thermocouple module in the X0 address slot of the D3–xx–1 base. If any expansion bases are used in the system, they must all be D3–xx–1 to be able to use this example. Otherwise, the conventional base addressing must be used.

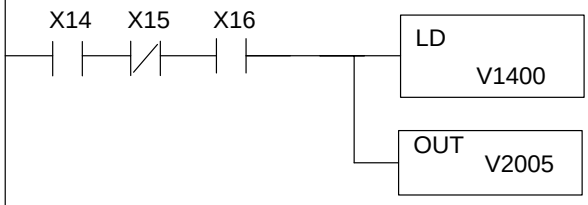


Channel 5 Select Bit States



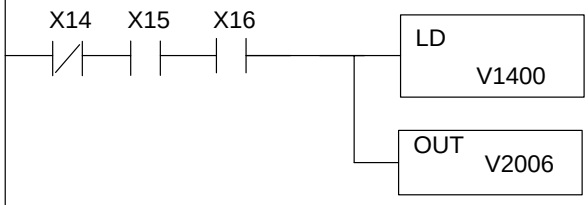
This writes channel five data to V2004 when bits X14, X15 and X16 are as shown.

Channel 6 Select Bit States



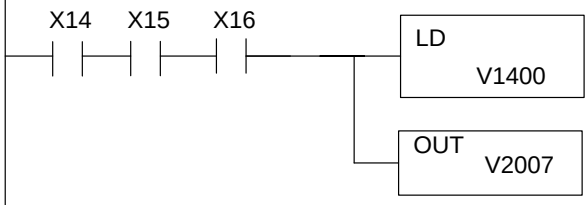
This writes channel six data to V2005 when bits X14, X15 and X16 are as shown.

Channel 7 Select Bit States



This writes channel seven data to V2006 when bits X14, X15 and X16 are as shown.

Channel 8 Select Bit States

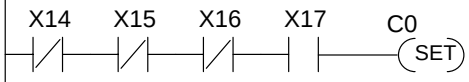


This writes channel eight data to V2007 when bits X14, X15 and X16 are as shown.

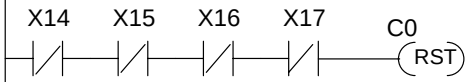
Using the Sign Bit

Channel 1 Selected

X17 is the sign bit when in module address 0.



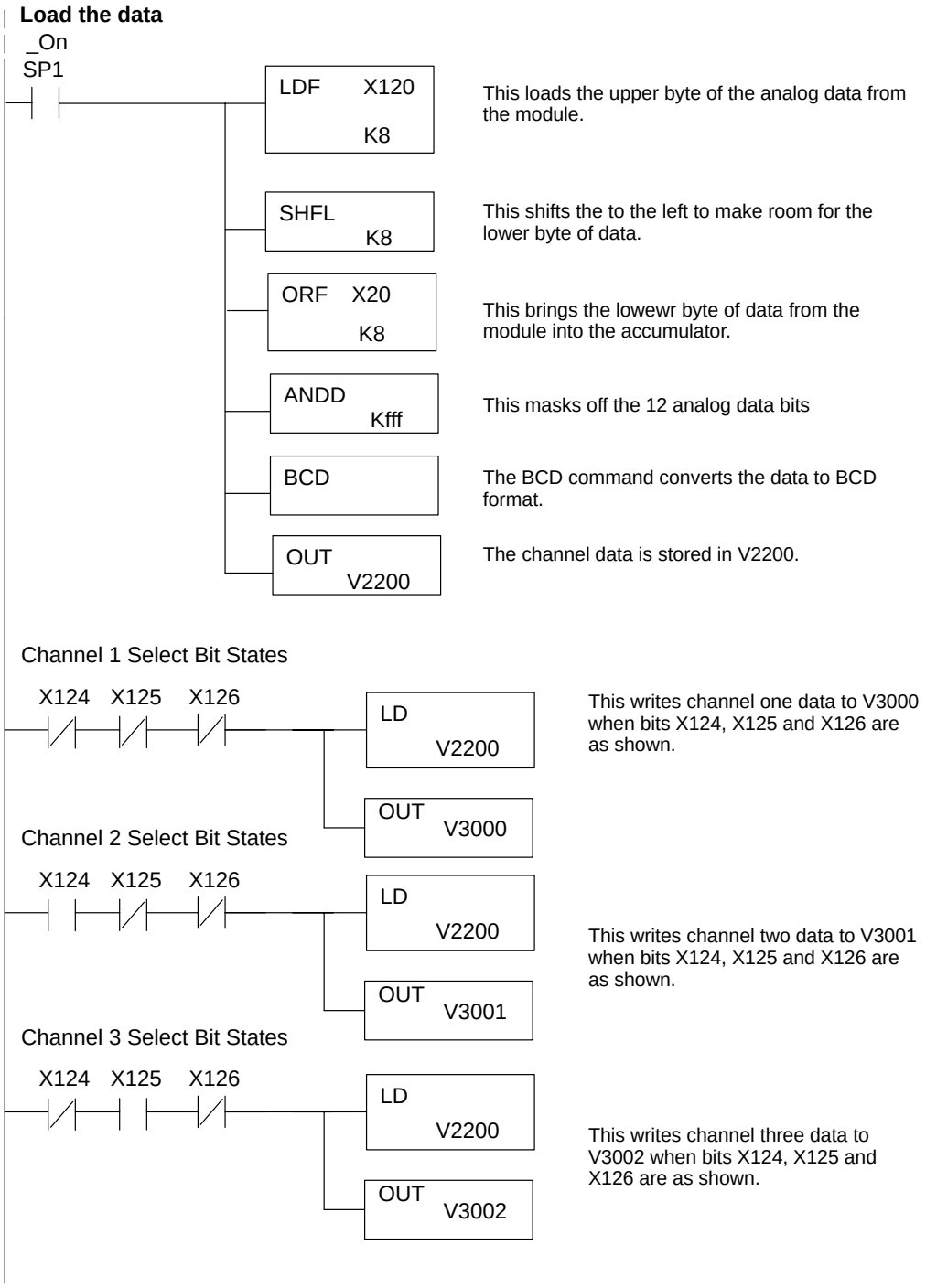
When the sign bit is on, the sign control relay (C0) is set, causing the temperature on channel one to be negative.



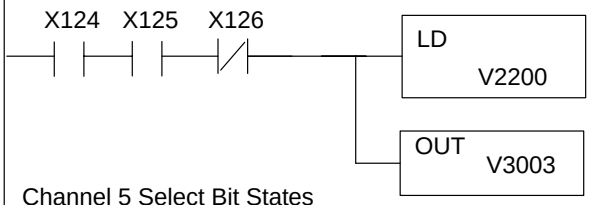
When the sign bit is not true, the sign bit control bit is reset, causing the temperature on channel one to be positive.

Multiplexing: DL350 with a Conventional DL305 Base

The example below shows how to read multiple channels on an F3–08THM Thermocouple module in the X20–X27 / 120 –127 address of a DL305 conventional base. The first six channels are shown.

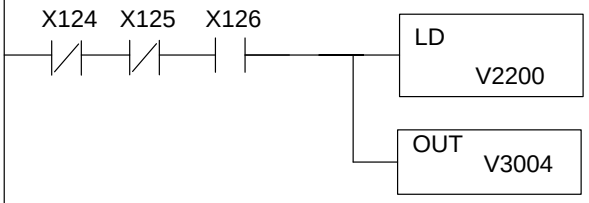


Channel 4 Select Bit States



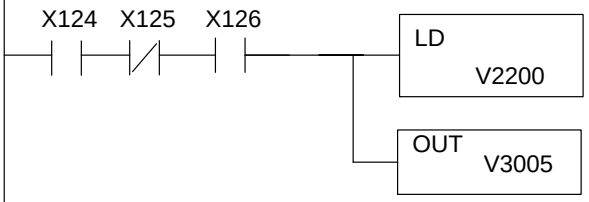
This writes channel four data to V3003 when bits X124, X125 and X126 are as shown.

Channel 5 Select Bit States



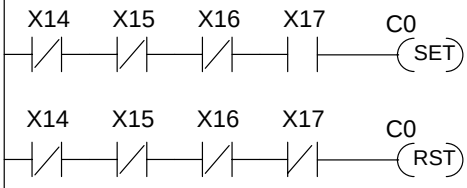
This writes channel five data to V3004 when bits X124, X125 and X126 are as shown.

Channel 6 Select Bit States



This writes channel six data to V3005 when bits X14, X15 and X16 are as shown.

Channel 1 Negative Temp



X17 is the sign bit when in module address 0.

When the sign bit is on, the sign control relay (C0) is set, causing the temperature on channel one to be negative.

When the sign bit is not true, the sign bit control bit is reset, causing the temperature on channel one to be positive.

Scaling the Input Data

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

You may have to make adjustments to the formula depending on the scale you choose for the engineering units.

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

H = high limit of the engineering unit range

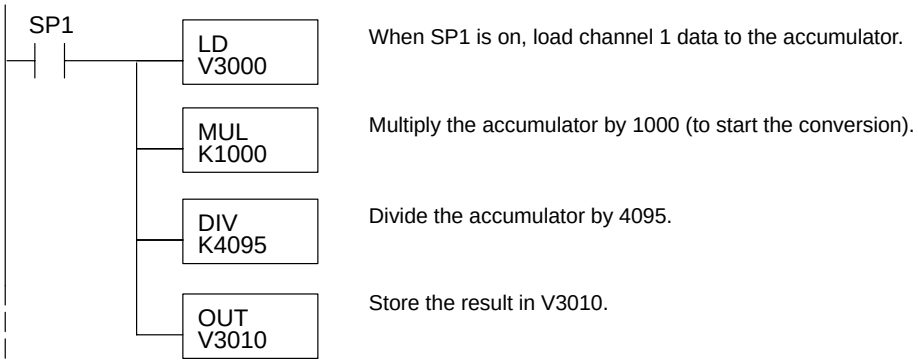
L = low limit of the engineering unit range

A = Analog value (0 – 4095)

For example, if you wanted to measure pressure (PSI) from 0.0 to 99.9 then you would have to multiply the analog value by 10 in order to imply a decimal place when you view the value with the programming software or a handheld programmer. Notice how the calculations differ when you use the multiplier.

Here is how you would write the program to perform the engineering unit conversion. This example assumes you have BCD data loaded into the appropriate V-memory locations using instructions that apply for the model of CPU you are using.

NOTE: This example uses SP1, which is always on. You could also use an X, C, etc. permissive contact.



Temperature and Digital Value Conversions

Since the thermocouple devices are non-linear, it is much easier to rely on published standards for conversion information. The National Bureau of Standards publishes conversion tables that show how each temperature corresponds to an equivalent signal level.

Millivolt and Digital Value Conversions

Sometimes it is helpful to be able to quickly convert between the signal levels and the digital values. This is especially helpful during machine startup or troubleshooting. The following table provides formulas to make this conversion easier.

mV Range	If you know the digital value ...	If you know the analog signal level ...
MV50 0 to 50 mV	$A = \frac{50D}{4095}$	$D = \frac{4095}{50}A$
MV100 0 to 100 mV	$A = \frac{100D}{4095}$	$D = \frac{4095}{100}A$

For example, if you are using a –2 (100mV) version and you have measured the signal as 30 mV, you would use the following formula to determine the digital value that should be stored in the register location that contains the data.

$$D = \frac{4095}{100}A$$

$$D = \frac{4095}{100}(30)$$

$$D = (40.95)\ (30)$$

$$D = 1229$$