SIEMENS

SIMATIC TI505

Thermocouple Input Module

User Manual

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Preface

This manual is a guide to help you set up, install, configure, calibrate, and troubleshoot the Series 505™ Thermocouple Input Module (PPX:505–7028). Additional information about installing, programming, and troubleshooting Series 505/Series500™ PLCs and their I/O modules is located in the following manuals.

- *SIMATIC® TI505™ Programming Reference Manual*, (2586546-0051)
- Installation and hardware manual(s) shipped with your Series 500/505 PLC

To order additional manuals, contact your Siemens Industrial Automation, Inc. distributor.

Agency Approvals

The Thermocouple Input Module complies with the standards of the following agencies:

- Underwriters Laboratories: UL Listed (Industrial Control Equipment)
- Canadian Standards Association: CSA Certified (Process Control Equipment)
- Factory Mutual Approved; Class I, Div. 2 Hazardous Locations
- Verband Deutscher Elektrotechniker (VDE) 0160 Clearance/Creepage for Electrical Equipment (Self-Compliance)

This product has been developed with consideration of the draft standard of the International Electrotechnical Commission Committee proposed standard (IEC-65A/WG6) for programmable controllers. Contact your Siemens Industrial Automation, Inc. distributor for a listing of the standards to which Series 505 complies.

Need Assistance?

If you need information that is not included in this manual, or if you have problems using the module, contact your your Siemens Industrial Automation, Inc. distributor or sales agent. If you need assistance in contacting your distributor or sales agent, call 1–800–964-4114 in the United States.

Chapter 1

Product Overview

1.1 General Description

Overview

The TI505 Thermocouple Input Module is a single-wide module that can be used with all Series 505 and Series 500 PLCs. This module mounts in a TI505 base. Series 500 PLCs can communicate with it through TI505 DBCs or RBCs.

Module Features

The module has the following features:

- Eight differential inputs
- ±50 mV input voltage range
- ANSI-defined thermocouple types J, K, T, E, R, S, N and mV can be used as input sources; one selection for all eight inputs
- 250-ms update time for one or all channels
- 14-bit full-scale data resolution
- Isolation: 1500 Vrms between input points, 1500 Vrms between the input section and the PLC
- Thermocouples can be any combination of grounded and ungrounded
- Open thermocouple probe detection
- Automatic cold junction compensation
- Engineering units (°F or °C) or scaled integer data formats
- Calibration requires precision mV source only
- All eight input points are calibrated simultaneously
- Cold junction can be calibrated independently
- Module uses solid state non-volatile memory for calibration parameters (no trim-pots)
- Removable user wiring connector
- Built-in diagnostics reports through error words

Additional specifications are listed in Appendix B.

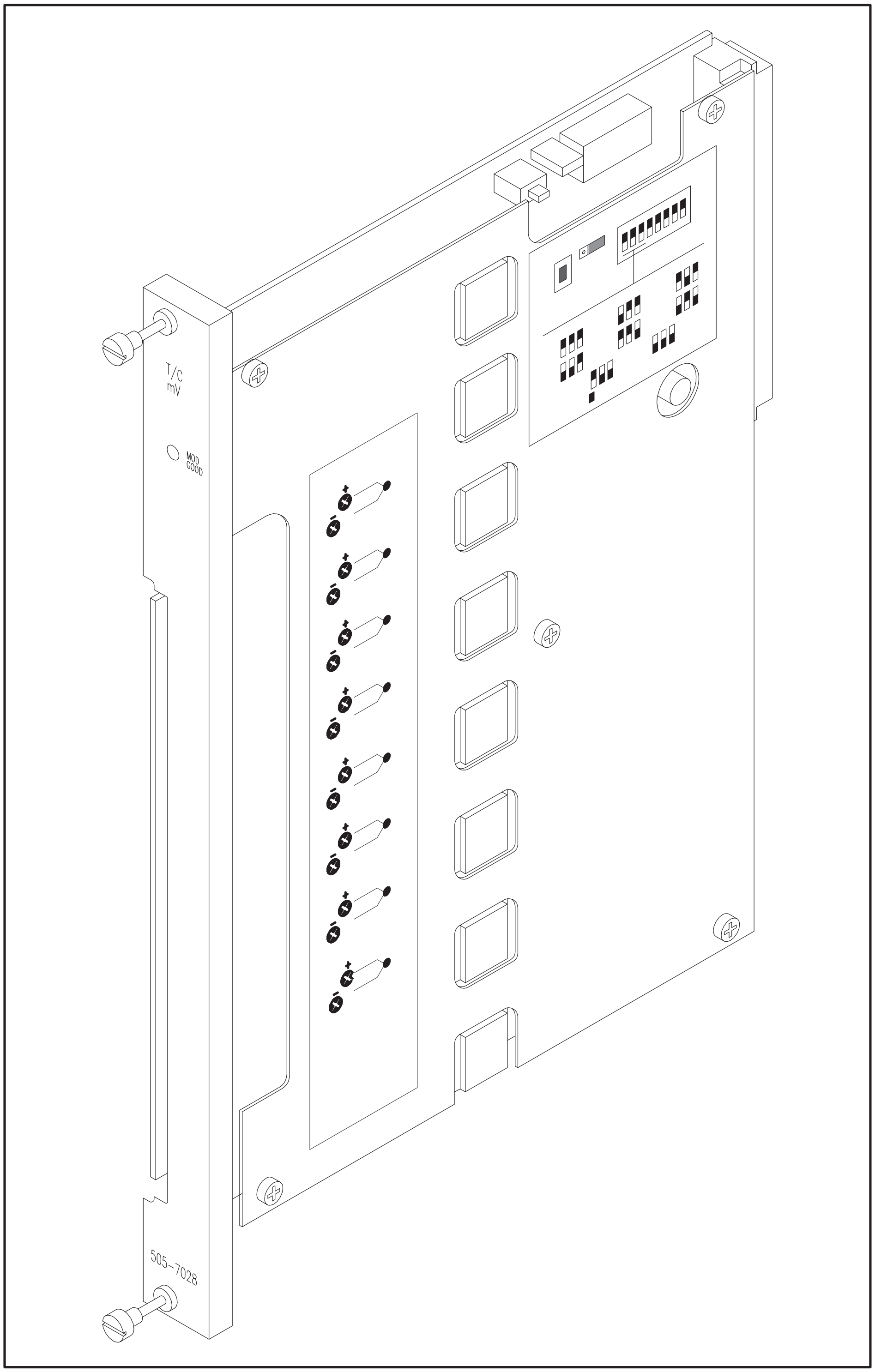

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Figure 1-1 Series 505 Thermocouple Input Module

1.2 Additional Feature Descriptions

Cold Junction Compensation

The module provides automatic cold junction (CJ) compensation for thermocouple input points. The connector temperature is measured by a sensor at the input connector. This value is then used to compensate for the small junction voltages that occur at the connector terminals.

Data Sampling Rate and Linearization

Inputs are sampled every 250 ms @ 60 Hz or 240 ms @ 50 Hz, providing digital line filtering. Input circuits also include a three-section, low-pass filter to provide a high level of noise rejection. NTIS (formerly NBS) standard equations are used for thermocouple readings to ensure accurate linearization in reported data. Linearization for type N probe assumes #28-gauge probe wire below 0°C, and #14-gauge probe wire above 0°C.

Data Word Resolution

The module provides at least 14-bit, full-scale resolution. With engineering units selected, the ±50 mV signal range is reported as a signed integer (±10,000). The module also provides improved resolution for temperature data by using a ×10 multiplier for °F and °C readings. The actual resolution of temperature data in degrees depends on the probe type, and the measurement temperatures within the probe range. Typical temperature resolution is 0.1°C.

You can also select scaled integer data format. Details on scaled integer appear in Section 3.3.

Power Required

Module power requirements (drawn from the base) are the following.

- +5 volt supply —typically 1.6 W; does not exceed 2.2 W
- –5 volt supply — less than 0.01 W

Probe Temperature Ranges

Table 1-1 shows the temperature ranges of the seven probe types supported by this module.

Table 1-1 Thermocouple Probe Type Temperature Ranges

Probe Type	Temperature Range	
	°C	°F
J	–210 to 760	–346 to 1400
K	–220 to 1320	–364 to 2408
T	–230 to 400	–382 to 752
E	–240 to 700	–400 to 1292
R	0 to 1768	32 to 3214
S	0 to 1768	32 to 3214
N	–200 to 1300	–328 to 2372

Chapter 2
Installing the Module

2.1 Overview

Installation Tasks

Figure 2-1 shows the general order in which you install the module.

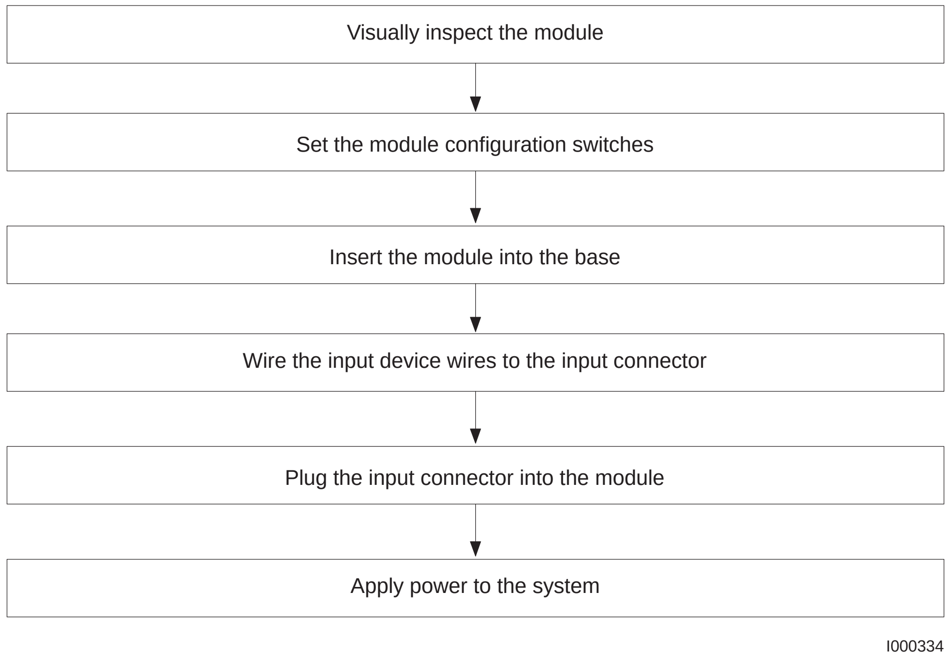

Figure 2-1 Flowchart of Installation

Handling the Module

Many integrated circuit (IC) devices are susceptible to damage by the discharge of static electricity. Follow the suggestions listed below to reduce the probability of damage to these devices when you are handling a controller, a base controller, or any of the I/O modules.

Both the module and the person handling the module should be at the same ground potential. Also, follow these guidelines.

- Transport the module in an anti-static container, or use antistatic material.
- Ensure that the work area has a conductive pad with a lead connecting it to a common ground.
- Ground yourself by making contact with the conductive pad and/or by wearing a grounded wrist strap.

Inspecting the Module

Inspect the module for any visible damage before setting any selectable features. If damage is detected, contact your Siemens Industrial Automation, Inc. distributor or sales agent for further instructions. If you need assistance in contacting your distributor or sales agent in the United States, call 1–800–964-4114.

2.2 Setting Options

Overview

Figure 2-2 shows locations of the store switch S1, cold junction CAL/RUN jumper J1, and dipswitch S2. Figure 2-3 shows module option settings.

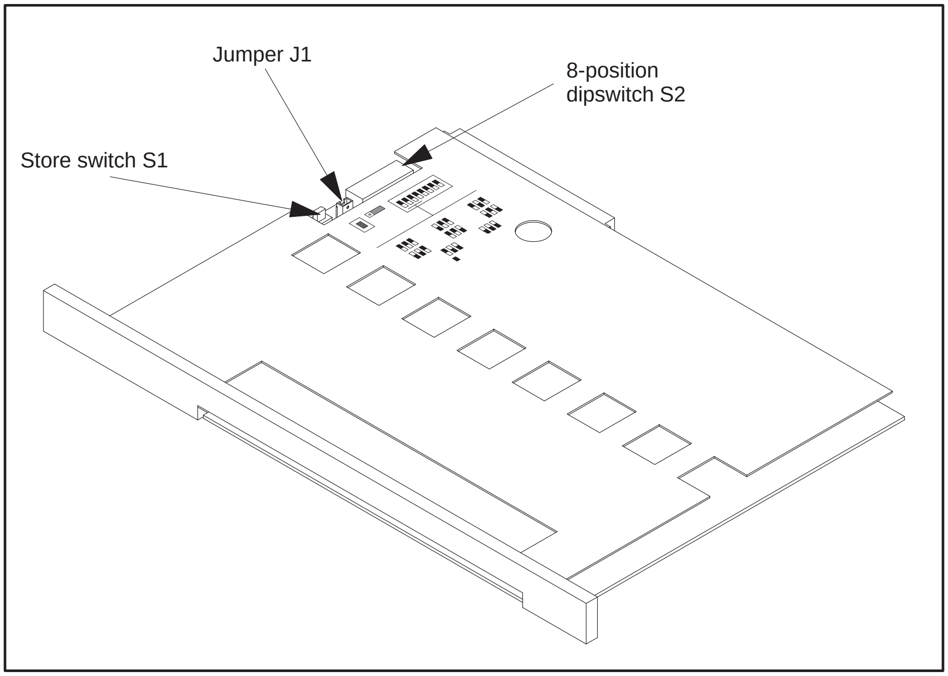

Figure 2-2 Jumper and Dipswitch Locations

Setting Input Type (Dipswitches 1, 2, and 3)

Figure 2-3 illustrates the configuration label on the module cover; the module is shipped with dipswitches and the cold junction jumper set in these default positions. As shown, the first three dipswitches are used to set the input type.

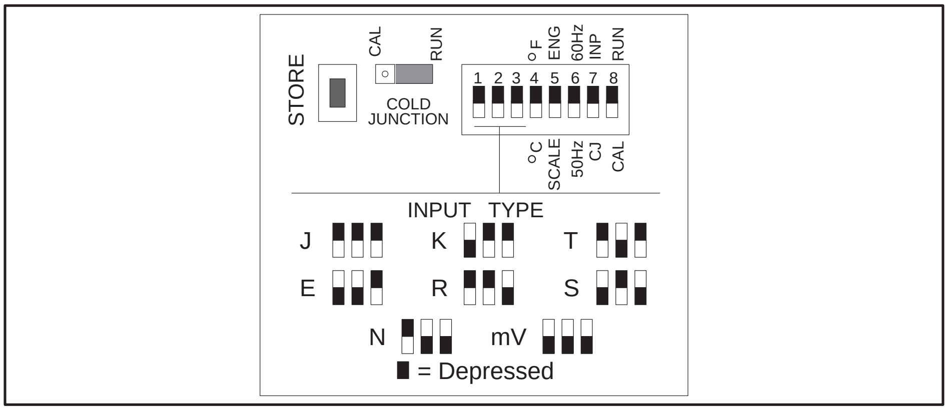

Figure 2-3 Setting Module Configuration

Setting °F/°C (Dipswitch 4)

Set the °F/°C (degrees Fahrenheit/Centigrade) switch to match the data format you want reported to the PLC when using engineering units.

Selecting Engineering or Scaling Format (Dipswitch 5)

When ENG (engineering) is selected, the module provides formatted data: ±50 mV as ±10000; thermocouple reading as (°C × 10) or (°F × 10). When SCALE (scaled integer) is selected, the module provides formatted data: ±50 mV as ±32000; thermocouple range as 0 to 32000.

Setting 50 or 60 Hz (Dipswitch 6)

For maximum noise rejection, set the 50 Hz/60 Hz switch to match the line frequency that is being used to power the system.

NOTE: The next three switches are provided for calibrating the module. The module has been calibrated at the factory and may be put into service after verifying that dipswitch 8 is in the RUN position.

Setting INP or CJ (Dipswitch 7)

The INP/CJ dipswitch is used to select whether the inputs or the CJ reference is to be calibrated. This dipswitch is only enabled when the RUN/CAL dipswitch is set to CAL.

Setting RUN or CAL (Dipswitch 8)

The RUN/CAL dipswitch is used to select the CAL mode when calibration is required.

Using the Store Switch

After completing a module calibration step, the STORE switch is used to store the changes in non-volatile memory.

2.3 Connecting the Input Wires

General Wiring Considerations

To minimize errors and the potential effects of external noise, follow these guidelines when connecting the module input wires.

- Extension wire, if used, and the connecting probe must be the same type of thermocouple wire.
- Use the shortest possible input wires (recommended maximum of 1,000 feet of extension wire). The measurement error is 6 µV or 0.006% of full-scale range (FSR) per 1,000 Ω of input lead resistance (500 Ω per lead).
- Avoid placing signal wires parallel to high-energy wires. If the two must meet, cross them at right angles.
- Avoid bending the wire into sharp angles.
- Use wireways for wire routing.
- When using shielded wires, ground the shield only at the source end for better noise immunity. If shielding at the source end is impractical, ground the shield to the chassis terminals of the module input connector, and run a wire from the chassis terminals to the earth ground on the base, as shown in Figure 2-5.

Wiring the Module Input Connector

Refer to Figure 2-4 when attaching wires to the module input connector. Normally, it is easier to first attach input wires to the connector, then plug the connector into the module. Also, follow these guidelines:

- Ensure that you observe thermocouple probe wire polarity; Table 2-1 shows lead compositions, colors, and polarities for the seven supported thermocouple probe types.
- Label the input wires, and record this information (along with module dipswitch configuration) in an appropriate location.

Table 2-1 Probe Type and Extension Wire Descriptions

Probe Type	Negative (–) Lead	Positive (+) Lead
J	Copper-Nickel (Red)	Iron (White)
K	Nickel-Aluminum (Red)	Nickel-Chromium (Yellow)
T	Copper-Nickel (Red)	Copper (Blue)
E	Copper-Nickel (Red)	Nickel-Chromium (Purple)
R	Platinum (Red)	Platinum-13 % Rhodium (Black)
S	Platinum (Red)	Platinum-10 % Rhodium (Black)
N	Nisil (Red)	Nicrosil (Orange)

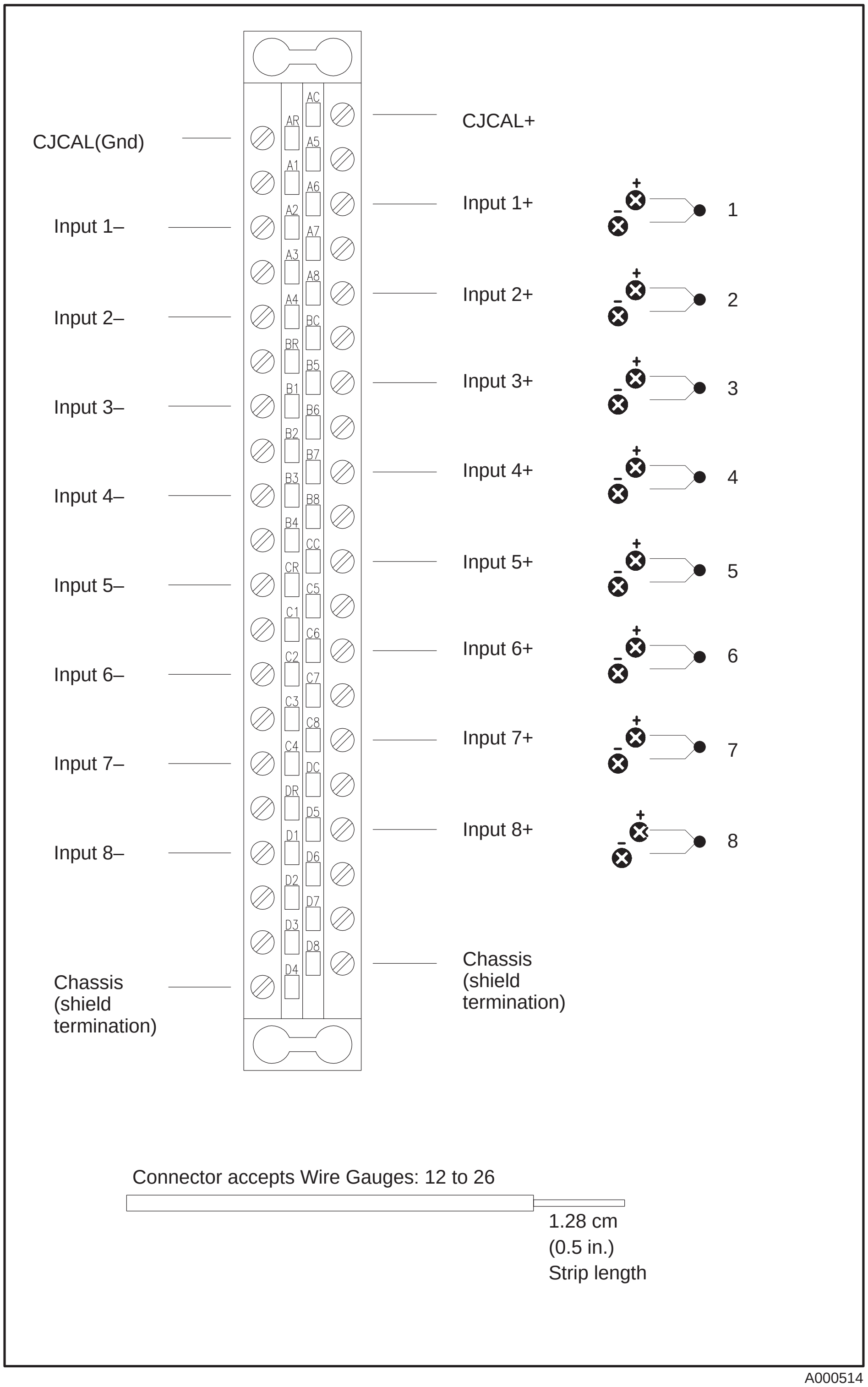

Figure 2-4 User Wiring Terminations

2.4 Inserting the Module Into the Base

⚠ **WARNING**

To minimize potential shock, turn off power to the I/O base and any modules installed in the base, before inserting or removing a module. Failure to do so may result in potential injury to personnel or damage to equipment.

Installing the Module

Install the module in a TI505 base. The thermocouple module performs better when placed away from high-energy switching sources. If possible, try to avoid installing the module adjacent to high-energy switching modules or other potential sources of EMI (electromagnetic interference). Also, avoid placing the module beside any device that produces excessive heat. Excessive heat can change the ambient temperature of the thermocouple CJ sensor, thereby distorting CJ measurement values.

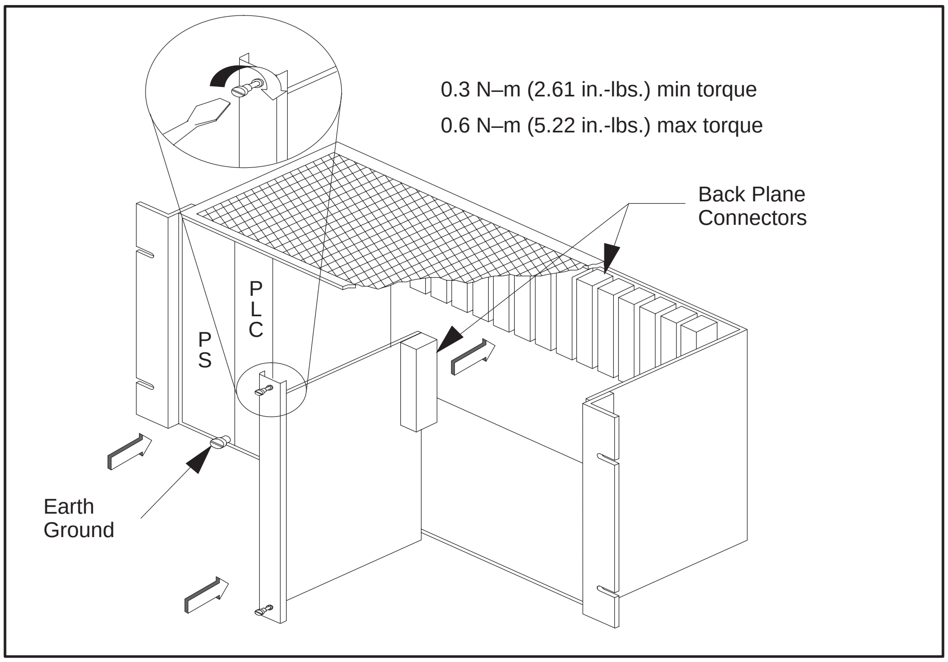

Figure 2-5 Inserting the Module Into the Base

Tightening Module Screws

When tightening the module screws, use the specified torque to achieve a good ground connection between the module bezel and the base.

Power Requirements

This module receives its power through the TI505 chassis backplane from the chassis power supply. The module requires a maximum of 2.2 W (1.6 W typical) of +5 V and 0.01 W of –5 V system power. Compute your power budget by adding these values to the requirements of all other modules in the I/O chassis to prevent overloading the base power supply.

Chapter 3

Placing the Module in Operation

3.1 Overview

Flow of Tasks

Figure 3-1 shows the general order in which you integrate the thermocouple module into your control system. Procedures needed to complete the first two tasks are covered in Chapter 2.

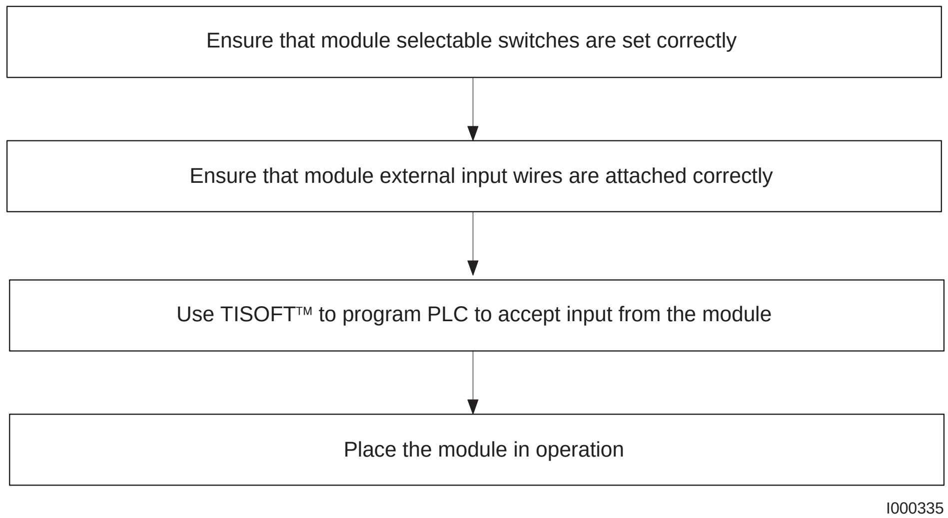

Figure 3-1 Flowchart of Operation

3.2 Programming the Controller

Programming Devices

You can use TISOFT with an IBM® PC/XT® or PC/AT®-compatible computer or other programming device to add Thermocouple Module configuration data into your PLC program. Refer to the *SIMATIC TI505 Programming Reference Manual* for specific details on designing a program.

Updating Module Configuration Data in the PLC

Fill in configuration screens as required. Figure 3-2 is a sample I/O module definition chart. Refer to your TISOFT manual for more detailed instructions including how to display the Configuration Charts, read your base(s), and write the data to the PLC.

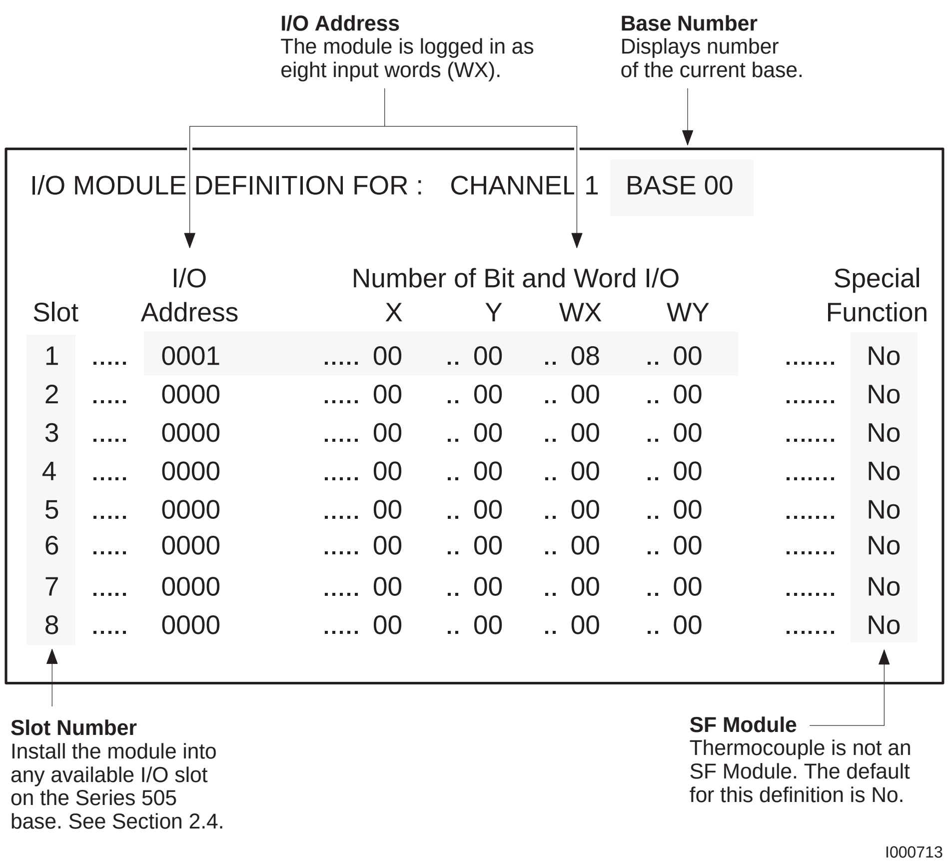

Figure 3-2 Sample I/O Definition Chart

3.3 Defining the Module’s Input to the Controller

Data Word Format

Figure 3-3 shows the format for a Thermocouple Module WX point (PLC input) word. Point measurements are reported as signed integers. The most significant bit (MSB) is used as a sign bit (1 denotes the sign is –). Sixteen numbers, 32752 through 32767, are used to report module errors.

Two types of data formatting are provided: engineering units (ENG) and scaled integer (SCALE).

- When ENG and mV are selected, ±50 mV is represented as ±10000. With ENG and a probe type selected, thermocouple values are presented as °C×10 or °F×10, depending on whether you select °C or °F.
- With SCALE and mV selected, ±50 mV is represented as ±32000. With SCALE and a probe type selected, the thermocouple range is scaled 0 to 32000. This feature is useful in conjunction with PID loop applications.

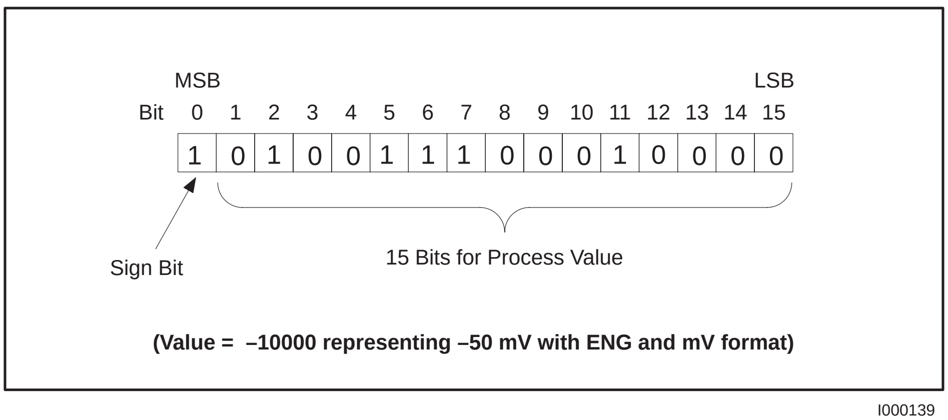

Figure 3-3 Word (WX) Bit Layout

3.4 Module Performance Considerations

Overview

The following sections explain performance characteristics when the module is set to operate in various operating modes. Consider this information carefully when evaluating module performance in your application.

Millivolt Performance Data

Table 3-1 shows module performance data when operating in the mV configuration. Typical performance is achieved when the module is re-calibrated in the user base; this allows the module to comprehend the precise conditions of the installation. Specification limits apply when the module is put into service as received from the factory.

Table 3-1 Millivolt Operating Characteristics

Characteristic	Typical	Specification Limit
Resolution	5 µV or 0.005%	6 µV or 0.006%
Repeatability	±10 µV or ±0.01%	±20 µV or ±0.02%
Mean accuracy	±30 µV or ±0.03%	±60 µV or ±0.06%
Temp coefficient	±10 µV/C or ±0.01%/C	±16 µV/C or ±0.016%/C
Over-/underrange	±55 mV	Same as typical
NOTE: Percentages refer to full-scale range (FSR) of 100 mV.		

With ENG selected, a full scale input of ±50 mV is presented to the PLC as signed integer ±10000. This means the module provides a resolution of 5 µV per count (1 in 20000) for the full-scale range of 100 mV. Overrange occurs at about +55 mV; underrange occurs at about –55 mV.

With SCALE selected, a full scale input of ±50 mV is presented to the PLC as signed integer ±32000:

Scaled integer = *mV x* 640.

Overrange occurs above +32751 (about 51.173 mV) and underrange occurs below –32768 (about –51.200 mV).

Thermocouple Performance Data

The module uses special circuits to determine the temperature of the user wiring connector when it is configured for thermocouple operation. The connector terminals often are referred to as the CJ, and the module makes corrections for error voltages that occur at this junction. These special circuits can contribute an additional maximum error of ±0.5°C.

NOTE: The module connector temperature can be monitored by installing a jumper wire (short) between input terminals of an unused channel.

Module Performance Considerations (continued)

Other sources that can contribute errors include:

- Standard wire errors for the thermocouple probe type and wire size used
- Mechanical stress on the thermocouple wire in the installation
- Lead wire resistance as described in Section 2.3
- Temperature gradient within the user wiring connector (Appendix A)
- Uneven heating of module and connector (Appendix A)
- Calibrating the module using non-precision voltage sources

NOTE: Table 3-1 through Table 3-4 describe the module performance and do not include errors from the external variables described above.

Table 3-2 shows performance with a J-type probe used between 0°C and 760°C (minimum probe output of 50 µV per °C). This table shows °C equivalents for resolution, repeatability, accuracy, and temperature coefficient (0.5°C in accuracy specification is first converted to µV at the ambient temperature and then the µV total is evaluated at the measured temperature).

Table 3-2 Module Performance Using J Probe Measuring 0 to 760°C

Characteristic	Typical	Specification Limit
Resolution	5 µV or 0.1°C	6 µV or 0.12°C
Repeatability	±10 µV or ±0.2°C	±20 µV or ±0.4°C
Mean accuracy	±(30 µV + 0.5°C) or ±1.1°C	±(60 µV + 0.5°C) or ±1.7°C
Temp coefficient	±10 µV/C or ±0.2°C/C	±16 µV/C or ±0.32°C/C
Over-/underrange	10°C beyond range limit	Same as typical

With ENG selected, data to the PLC are °C×10 or °F×10. Overrange occurs at about 10°C above maximum temperature and underrange occurs at about 10°C below minimum temperature in range.

With SCALE selected, data are scaled 0 to 32000, with 0 representing the minimum temperature in range and 32000 representing the maximum temperature in range. Intermediate temperatures have scaled integer values determined by the relationship:

$$Scaled\ Integer = \frac{(Temp - min\ temp)}{(Max\ temp - min\ temp)} \times 32000$$

For example, overrange for probe type J gives:

$$Scaled\ integer\ overrange = \frac{(770\ ℃ - (-210\ ℃))}{(760\ ℃ - (-210\ ℃))} \times 32000 = 32330$$

Both typical and worst case performances for any supported probe type can be determined by using Table 3-5 and Table 3-2. For example: to find module performance for Probe Type J measuring near –210°C, use Table 3-5 and find that the rate-of-change for J probe at –210°C is about 20 µV/C. With ambient temperature of 25°C, 0.5°C is 26 µV. Results appear in Table 3-3.

Table 3-3 Module Performance Using J Probe Measuring Near –210°C

Characteristic	Typical	Specification Limit
Resolution	5 µV or 0.25°C	6 µV or 0.3°C
Repeatability	±10 µV or ±0.5°C	±20 µV; ±1.0°C
Mean accuracy	±(30 µV + 0.5°C) or ±2.8°C	±(60 µV + 0.5°C); ±4.3°C
Temp coefficient	±10 µV/C or ±0.5C/C	±16 µV/C; ±0.8C/C

Table 3-4 defines the overall performance of the module when it is configured for thermocouple operation. This table is derived from the accuracy parameters of Table 3-2 and probe characteristics identified in Table 3-5.

Table 3-4 Accuracy for All Supported Probe Types Above 0°C

Probe Type	Typical Mean Accuracy	Typical Temperature Coefficient	Limits for Mean Accuracy	Limits for Temperature Coefficient
J	±1.1°C	±0.20°C/C	±1.7°C	±0.32°C/C
K	±1.4°C	±0.29°C/C	±2.3°C	±0.46°/C
T	±1.3°C	±0.26°/C	±2.0°C	±0.41°CC
E	±1.0°C	±0.17°C/C	±1.5°C	±0.27°C/C
**R	±2.8°C	±0.83°C/C	±5.3°C	±1.33°C/C
**S	±3.0°C	±0.91°C/C	±5.7°C	±1.45°C/C
N	±1.7°C	±0.38°C/C	±2.8°C	±0.62°C/C
**above 800°C for R & S				

Thermocouple Probe Output Characteristics

Thermocouple probes are not ideal devices, and overall system accuracy depends upon the probe type being used and the measuring point within the probe range. Table 3-5 shows typical probe output characteristics.

Table 3-5 T/C Probe Output Characteristics

Probe Type	Temperature (°C)	Rate-of-change (μV/°C)
J	Max 760 °C	64 μV / °C
	275 °C	55 μV / °C
	25 °C	52 μV / °C
	0 °C	50 μV / °C
	Min –210 °C	20 μV / °C
K	Max 1320 °C	35 μV / °C
	550 °C	43 μV / °C
	25 °C	40 μV / °C
	0 °C	39 μV / °C
	Min –220 °C	12 μV / °C
T	Max 400 °C	62 μV / °C
	85 °C	46 μV / °C
	25 °C	41 μV / °C
	0 °C	39 μV / °C
	Min –230 °C	11 μV / °C
E	Max 700 °C	80 μV / °C
	230 °C	75 μV / °C
	25 °C	61 μV / °C
	0 °C	59 μV / °C
	Min –240 °C	13 μV / °C
R	Max 1768 °C	12 μV / °C
	884 °C	12 μV / °C
	25 °C	6 μV / °C
	Min 0 °C	5 μV / °C
S	Max 1768 °C	11 μV / °C
	884 °C	11 μV / °C
	25 °C	6 μV / °C
	Min 0 °C	5 μV / °C
N	Max 1300 °C	36 μV / °C
	550 °C	39 μV / °C
	25 °C	27 μV / °C
	0 °C	26 μV / °C
	Min –200 °C	10 μV / °C

Chapter 4

Troubleshooting the Module

4.1 Using Error Words to Identify Problems

The Thermocouple Input Module contains software routines that can detect hardware and software errors in the module and alert the PLC to the fault. During normal operation, each module data word (corresponding to an input point) reports an individual sensor reading to the PLC. Valid data word ranges depend on the specific thermocouple probe or mV input being used. When a single input fault is detected, a unique error word between 32752 and 32767 replaces the point data word. The error word value continues to be reported until the fault is cleared.

Table 4-1 contains a list of error words that are reported to the PLC. These error words may be used as a guide in troubleshooting your mV- or temperature-sensing system to determine whether the problem is in the module, in the external wiring and sensor, or in the programming of the module. If the fault is in the module, contact your Siemens Industrial Automation, Inc. distributor for further information and assistance.

Table 4-1 Thermocouple Module Error Words

Signed Integer	Hex	Problem	Comment/Corrective Action
32767	7FFF	Failed module	Failure is reported to PLC; MODULE GOOD indicator is off. Repair or replace module as required.
32766	7FFE	Channel underrange	Input signal level is below normal input range. Check process to determine if it is actually low or, if the thermocouple or mV transmitter is faulty. Module could be out of calibration.
32765	7FFD	Channel overrange	Input signal level is above normal input range. Check process to determine if it is actually high or, if the thermocouple or mV transmitter is faulty (if you are using thermocouples, the most likely cause is an open probe). Module could also be out of calibration.
32764	7FFC	EEROM storage error	Re-calibration required; if error persists, repair or replace the module.
32763	7FFB	Faulty input calibration	Calibration procedure was completed but this channel would not accept all data points; re-calibration is required. If error persists, repair or replace module.
32762	7FFA	CJ out-of-range	Check calibration jumper position; re-calibrate the CJ. If problem still persists, repair or replace the module.
32761	7FF9	Incomplete input calibration	Requires power cycle or re-calibration to clear. Old values are restored after power cycle if the module is not re-calibrated.
32760	7FF8	CJ calibration incomplete	Requires power cycle or re-calibration to clear. Old values are restored after power cycle if the module is not re-calibrated.
32759	7FF7		To be defined as required.
32758	7FF6		
32757	7FF5		
32756	7FF4		
32755	7FF3		
32754	7FF2		
32753	7FF1		
32752	7FF0	Calibration mode	CAL/RUN switch is set to the CAL position; change to RUN.

By incorporating an error-detection routine in your relay ladder logic (RLL) program, you can provide alarms to signal faults detected by the module. Figure 4-1 contains a general example of an error-detection routine, as described in the following statements.

- The first rung loads number 32751 into address location V1, and it loads number 32765 into address location V2.
- The second rung compares WX1 (representing one point on the thermocouple input module) with 32751; if WX1 is greater, C3 turns on.
- The third rung compares WX1 (representing one point on the thermocouple input module) with 32765; if WX1 is equal, C5 turns on.

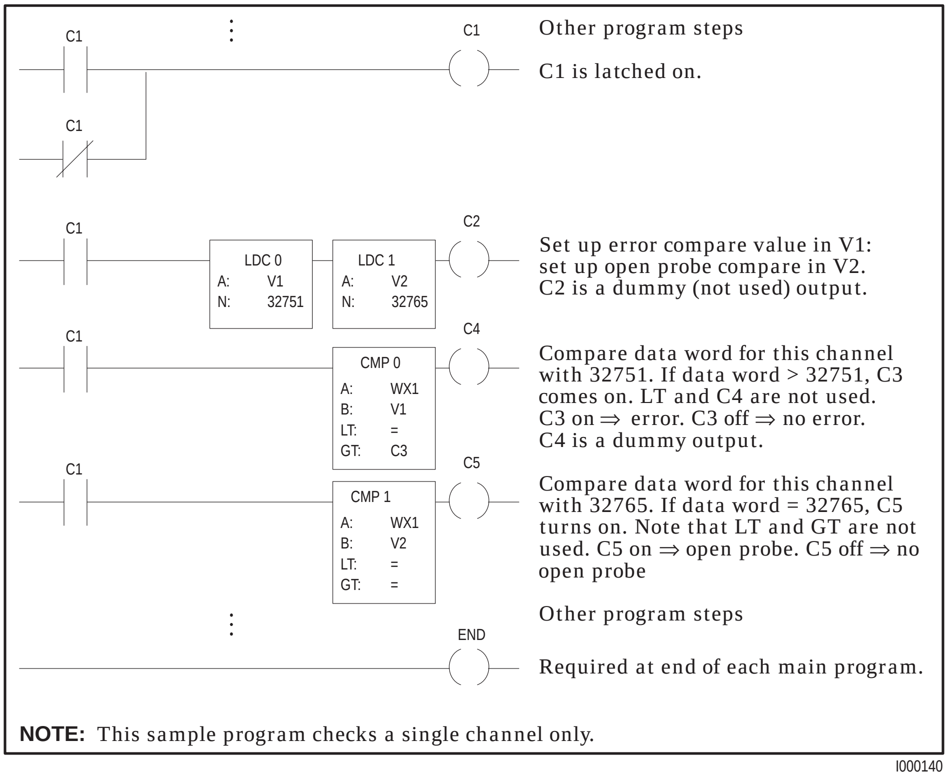

Figure 4-1 RLL Example for Error Detection

4.2 Identifying Problems Without Error Words

Some problems with wiring, software, or programming do not report error words to the PLC. If you suspect a problem, but no error word is reported, check to see if one of the following conditions exists.

- The MODULE GOOD indicator is off.
- A module word value (read by the PLC) is not an expected value.

Table 4-2 Causes and Corrective Action for Faulty Operation

Symptom	Probable Cause	Corrective Action
MODULE GOOD indicator is off	Base or PLC is off	Turn base or PLC on.
	Software failure	Power cycle the module to attempt to clear the failure.
	Module not fully seated in base	Re-install module in the base.
	Defective module	Replace module.
Incorrect readings	Wrong connections	Trace wiring to ensure it is wired correctly.
	Noise on signal wire	Use shielded wire — check wire routing.
	Not logged in properly for the program	Perform AUX 43, or read the I/O configuration.
	Thermocouple or wiring failure	Check the thermocouple, extension wire, and the connectors.
	Module out of calibration	Re-calibrate the module.
	Error word	Refer to Table 4-1 for problem and suggested corrective action.
	Module configured wrong	Check dipswitch settings.

NOTE: If you cannot resolve your problem, contact your Siemens Industrial Automation, Inc. distributor in the U. S. for further assistance.

Appendix A

Calibrating the Module

A.1 Preparing to Calibrate the Module

Overview

Although the Thermocouple Input module does not require calibration at installation, you should set up a routine calibration schedule. For most applications, annual calibration is adequate. If you operate outside the ambient temperature range of 20°C to 30°C, re-calibration at the current ambient temperature is recommended. Also, to ensure minimum variation in thermocouple accuracy, more frequent calibration may be required.

The calibration process is not difficult. A precision voltage source that can supply 0 to 600 mV with 10 µV accuracy is all that is required, although a euro-extender card is helpful. You need access to dipswitches 6, 7, and 8; the jumper plug; and the STORE pushbutton switch.

Flow of Tasks

Figure A-1 shows the general order in which you calibrate the module.

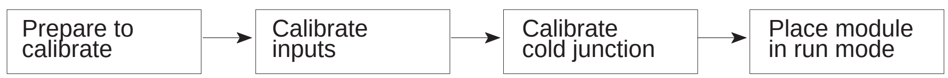

Figure A-1 Flowchart of Calibration

Preliminary Steps

Review the following procedures and comments prior to starting the calibration process.

- Set dipswitch 6 (50 Hz/60 Hz) to match your system power frequency.
- For easy access to switches, place the module on a standard VME extender board (available from Schroff, part number 20800–188, as well as other vendors). or in a base slot with at least three empty positions to the right of the module.
- Apply power to the base and Thermocouple module for at least 15 minutes prior to calibration.
- Calibrate all input channels at the same time.

NOTE: If dipswitch 6 is changed during the calibration procedure, repeat the procedure.

NOTE: If you are operating the module with mV inputs, it is not necessary to calibrate the CJ; calibration procedures can be performed independently.

A.2 Calibrating Inputs

Follow these procedures to calibrate thermocouple module inputs (INP). Refer to the user wiring label or to Figure A-2 for connector terminal assignments.

1. Set dipswitch 7 to INP.
2. Set dipswitch 8 to CAL. If the MODULE GOOD indicator flashes, and error word 7FF0 is reported to module WX locations (in the PLC), then the module is in calibration mode.
3. Using copper wire, strap all eight negative input terminals together on connector.
4. Strap all eight positive input terminals together.
5. Observing correct polarity, attach a precision –50 mV source to the eight parallel inputs.
6. Wait approximately 30 seconds for the circuits to stabilize, then press the STORE pushbutton. The MODULE GOOD indicator goes out for approximately 5 seconds; after the data is read, the indicator begins flashing again.
7. Apply 0 mV (short) to the parallel inputs.
8. Wait approximately 30 seconds for the circuits to stabilize, then press the STORE pushbutton. The MODULE GOOD indicator goes out for approximately 5 seconds; after the data is read, the indicator begins flashing again.
9. Attach a precision +50 mV voltage source to the parallel inputs.
10. Wait approximately 30 seconds for the circuits to stabilize, then press the STORE pushbutton. The MODULE GOOD indicator goes out for approximately 5 seconds. The data is read and a curve-fitting algorithm is used to compute correction factors. When this process is finished, the indicator begins flashing again.
11. Return the CAL/RUN switch to RUN. The MODULE GOOD indicator goes out for at least two seconds while the system is updated. When the process is complete, the indicator returns to a steady on state. Input calibration is now complete.

NOTE: If calibration was not successful, the MODULE GOOD indicator goes off and remains off until the unit is power-cycled or re-calibrated. Also, error code 7FF9 or 7FFB is sent to the module WX locations to indicate the incomplete or faulty calibration.

A.3 Calibrating Cold Junction

Follow these procedures to calibrate the CJ. Refer to the user wiring label or to Figure A-2 for connector terminal assignments.

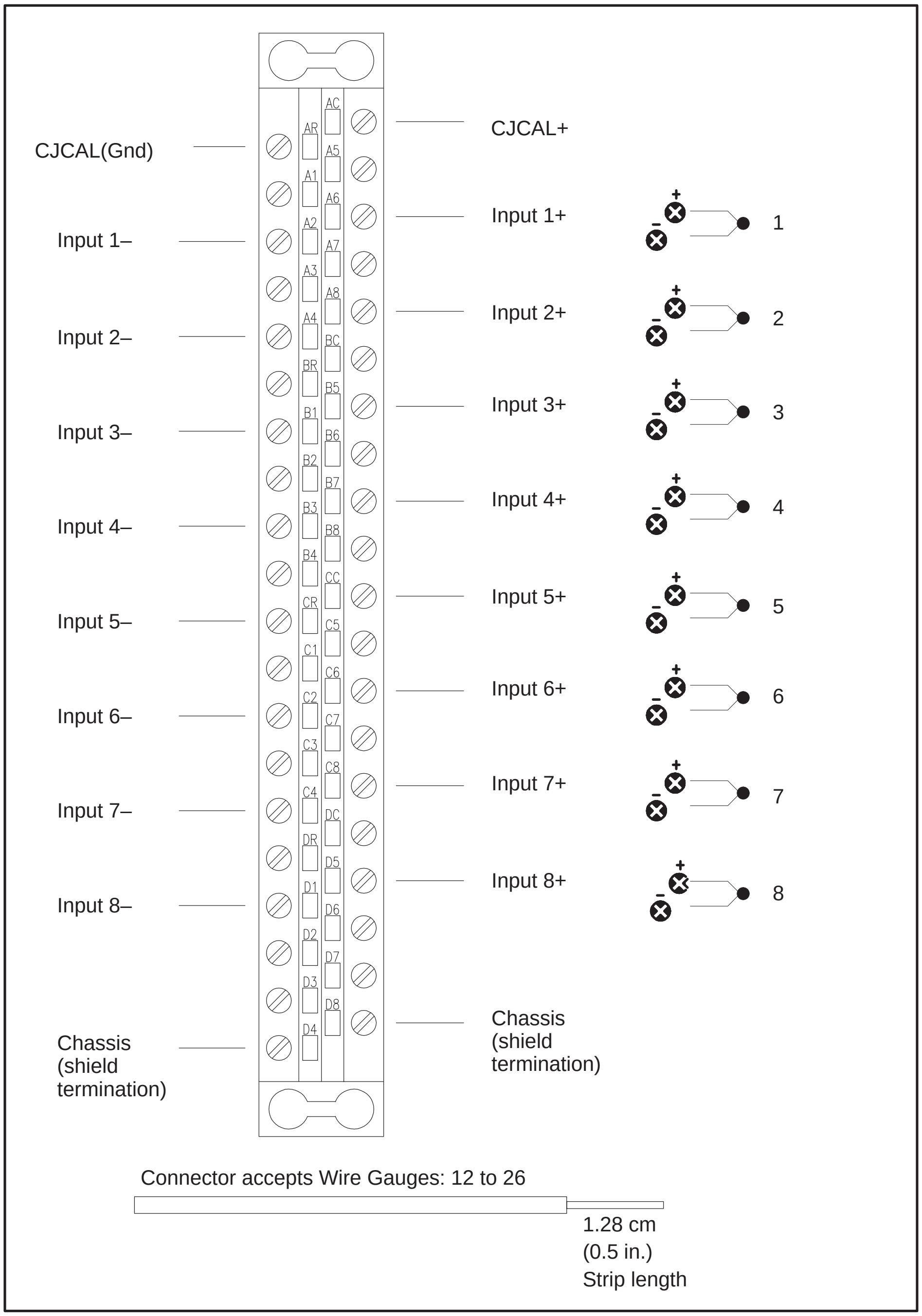

Figure A-2 User Wiring Terminations

1. Set dipswitch 6 to match your system power frequency.

2. Set dipswitch 7 to CJ; set dipswitch 8 to CAL. These conditions indicate that the module is in calibration mode: the MODULE GOOD indicator flashes, and error word 7FF0 is reported to module WX in the PLC.

3. Move the cold junction (CJ) jumper plug to the CAL position; see Figure A-3.

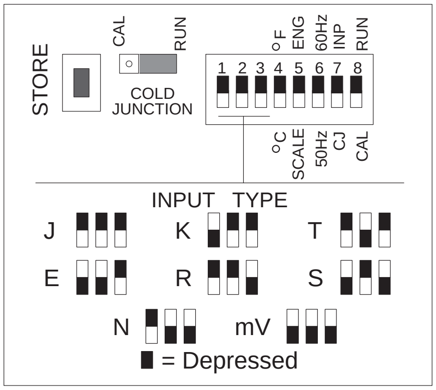

Figure A-3 Setting Module Configuration

4. Observing correct polarity, apply a precision voltage of 15 mV to the connector CJ CAL terminals. (This is a new value; see pages A-6 through A-10.)

5. Wait approximately 5 seconds for the circuits to stabilize, then press the STORE pushbutton. The MODULE GOOD indicator goes out for approximately 5 seconds; after the data is read, the indicator begins flashing again.

6. Adjust the precision voltage to 615 mV. (This is a new value; see pages A-6 through A-10.)

7. Wait approximately 5 seconds for the circuits to stabilize, then press the STORE pushbutton. The MODULE GOOD indicator goes out for approximately 5 seconds; after the data is read, the indicator begins flashing again.

8. Now adjust the precision voltage to 315 mV. (This is a new value; see pages A-6 through A-10.)

9. Wait approximately 5 seconds for the circuits to stabilize, then press the STORE pushbutton**.** The MODULE GOOD indicator goes out for approximately 5 seconds. The data is read and a curve-fitting algorithm is used to compute correction factors. When this process is finished, the indicator begins flashing again.

10. Disconnect the precision voltage source from the input connector.

11. Return the CAL/RUN switch to RUN and the CJ/INP switch to INP. The MODULE GOOD indicator goes out for at least two seconds while the system is updated. When the process is complete, the indicator returns to a steady state.

12. Re-install CJ jumper plug to RUN position. CJ calibration is complete.

NOTE: If a step was missed and calibration is incomplete, the MODULE GOOD indicator goes off and remains off until the unit is power-cycled or re-calibrated. Also, error code 7FF8 is sent to the module WX locations to indicate incomplete calibration.

Changes to the CJ Calibration Procedure

The calibration voltages for factory and field Cold Junction calibration have been changed to compensate for a small offset temperature between the CJ sensor and the average temperature of the contacts within the connector. Previously, the calibration voltages were 0 mV, 300 mV, and 600 mV. The change to 15 mV, 315 mV, and 615 mV provides an offset correction of 1.5°C or 2.7°F.

Although this offset is small compared to Thermocouple Probe Standard Wire Errors (±4°F to ±10°F for a J probe), the change reduces the mean offset error between the CJ sensor and connector to about ±1.0°F, depending on the influences described in sections 2.4 and 3.4.

Field Connector Errors during Thermocouple Measurement

Because the field connector does not have much thermal mass, a temperature gradient can exist, from top to bottom, from 0.4°F to as much as 2.6°F, depending on forced air circulation, radiant heating, etc. The top terminals are usually warmer. The calibration procedure cannot account for this on a channel-by-channel basis, so the Channel 5 terminals are used as an average reference for the following procedures.

Additional errors, typically less than ±0.2°F, can be caused by differences in the connector terminal composition.

NOTE: Connector errors are not included in the published accuracy specification; the direction and magnitude of these errors depend on the installation details. Refer to section 3.4.

Higher Precision Calibration: Method 1

Follow the steps below for calibration with an accurate, external method of temperature measurement:

1. With the unit at “INSTALLED AMBIENT TEMPERATURE” and a precision voltage source, perform the Input calibration procedure.
2. Use the former calibration voltages of 0 mV, 300 mV, and 600 mV, and perform the CJ calibration.
3. Install a jumper wire in the Channel 5 position.
4. With the unit operating in T/C mode and °C, record the PLC reading for the Channel 5 position. This represents the temperature used for the CJ correction by the software.
5. Under the conditions of step 4., obtain the temperature of the Channel 5 terminals with an *external precision measurement system* in °C.
6. Determine the difference between the PLC reading for Channel 5 and the externally measured temperature for the same connector terminals.
7. For each degree C difference, add 10.0 mV to the CJ voltages used in step 2. Perform the CJ calibration again.

   For example, if the difference is determined to be 0.8°C, use 8 mV, 308 mV, and 608 mV as the calibration voltages for the CJ procedure.

Calibrating Cold Junction (continued)

The results from using this higher precision calibration, with an accurate, external method of temperature measurement, follow:

- Errors due to the temperature coefficients of the internal components can be reduced or eliminated by calibrating the unit at the "INSTALLED AMBIENT TEMPERATURE."
- The small error of the CJ sensor (guaranteed to be less than 0.5°C) is accounted for by determining the CJ offset with steps 4. and 5.
- Step 5. provides for centering the CJ calibration within the temperature gradient of the connector.

Example of a Worst-Case Error

After this calibration has been completed, the errors internal to the module are less than ±50 µV (±1.8°F for a J probe). To arrive at a worst-case error, consider:

- The variance within the connector of ±1.3°F, and
- The error from non-homogenous materials of ±0.2°F.

The result is a worst-case error of ±3.3°F, using a type J probe with measurements above 0°C.

Typical Mean Accuracy

Typical module error is within ±30 µV (±1.1°F for a J probe). The temperature gradient within the connector is usually less than ±0.5°F. Therefore, the typical mean accuracy is ±1.6°F, after the precision calibration described above has been made.

Higher Precision Calibration: Method 2

Follow the steps below for calibration without an external method of temperature measurement:

1. With the unit at "INSTALLED AMBIENT TEMPERATURE" and a precision voltage source, perform the Input calibration procedure.
2. Use the newly published CJ calibration voltages of 15 mV, 315 mV, and 615 mV to perform the CJ calibration.

The results from using this higher precision calibration, without an external method of temperature measurement, follow:

- Errors due to the temperature coefficients of the internal components can be reduced or eliminated by calibrating the unit at the "INSTALLED AMBIENT TEMPERATURE."
- Using the new CJ calibration voltages, the offset error between the CJ sensor and the middle terminals of the connector should be less than ±1.0°F.

Example of a Worst-Case Error

After this calibration has been completed, the errors internal to the module are less than ±50 μV (±1.8°F for a J probe). To arrive at a worst-case error, consider:

- The variance within the connector of ±1.3°F; and
- The error from non-homogenous materials of ±0.2°F; and
- ±1.0°F for the CJ connector terminals offset error.

The result is a worst-case error of ±4.3°F, using a type J probe with measurements above 0°C.

Typical Mean Accuracy

Typical module error is within ±30 μV (±1.1°F for a J probe). The temperature gradient within the connector is usually less than ±0.5°F, and the CJ to connector terminals offset error is ±1.0°F. Therefore, the typical mean accuracy is ±2.6°F, after the precision calibration described above has been made.

To determine the accuracy limits for Thermocouple Probe types (other than type J), convert the ±50 μV and ±30 μV figures to temperature using Table A-1.

NOTE: The CJ offset must be limited to about 3°C, or 30.0 mV. Greater offsets are not feasible because they can create problems with the CJ calibration auto-ranging function. This CJ auto-ranging function allows the product to automatically recognize which of the three calibration voltages is being applied during calibration.

Calibrating Cold Junction (continued)

Table A-1 T/C Probe Output Characteristics

Probe Type	Temperature (°C)	Rate-of-change (µV/°C)
J	Max 760 °C	64 µV / °C
	275 °C	55 µV / °C
	25 °C	52 µV / °C
	0 °C	50 µV / °C
	Min –210 °C	20 µV / °C
K	Max 1320 °C	35 µV / °C
	550 °C	43 µV / °C
	25 °C	40 µV / °C
	0 °C	39 µV / °C
	Min –220 °C	12 µV / °C
T	Max 400 °C	62 µV / °C
	85 °C	46 µV / °C
	25 °C	41 µV / °C
	0 °C	39 µV / °C
	Min –230 °C	11 µV / °C
E	Max 700 °C	80 µV / °C
	230 °C	75 µV / °C
	25 °C	61 µV / °C
	0 °C	59 µV / °C
	Min –240 °C	13 µV / °C
R	Max 1768 °C	12 µV / °C
	884 °C	12 µV / °C
	25 °C	6 µV / °C
	Min 0 °C	5 µV / °C
S	Max 1768 °C	11 µV / °C
	884 °C	11 µV / °C
	25 °C	6 µV / °C
	Min 0 °C	5 µV / °C
N	Max 1300 °C	36 µV / °C
	550 °C	39 µV / °C
	25 °C	27 µV / °C
	0 °C	26 µV / °C
	Min –200 °C	10 µV / °C

Appendix B
Specifications

Table B-1 Environmental Specifications

Operating temperature	0° to 60°C (32° to 140°F)
Storage temperature	–40° to 70°C (–40° to 158°F)
Relative humidity	5% to 95% noncondensing
Pollution degree	2, IEC 664, 664 A
Vibration: Sinusoidal Random	 IEC 68-2-6, Test Fc: 0.15 mm peak-to-peak, 10–57 Hz; 1.0 g, 57–150 Hz NAVMAT P–9492 or IEC 68–2–34, Test Fdc with 0.04 g^2/Hz, 80–350 Hz, and 3 dB/octave rolloff, 80–20 Hz and 350–2000 Hz at 10 min/axis
Impact shock	IEC 68–2–27. Test Ea half sine, 15 g, 11 ms
Electrostatic discharge	IEC 801, Part 2, Level 4, (15 kV)
Noise immunity Conducted On user powerlines	 IEC 801, Part 4, Level 3 MIL STD 461B, CS01, CS02, CS06 IEC 255-4, IEEE 472
Noise immunity (Radiated)	 IEC 801, Part 3, Level 3 MIL STD 461B, RS01, RS02, RS03
Corrosion protection	All parts are corrosion-resistant or are plated or painted as corrosion protection.
Torque for bezel screws	0.3 Nm (2.61 in.-lbs.) minimum 0.6 Nm (5.22 in.-lbs.) maximum
Weight and dimensions of packed module	2 lbs., 9 oz; 12.75″ × 13.5″ × 3.75″
Weight and dimensions of unpacked module	1 lb., 3 oz; 10.5″ × 8.0″ × 0.8″

Table B-2 Electrical/Performance Specifications

Form factor	8 channels in single-wide Series 505 module.
Signal range	–50 mV to +50 mV; full-scale range (FSR) of 100 mV.
TC input types	J, K, T, E, R, S, N, mV; all channels same type, selected with dipswitch on circuit board.
Isolation (channel-channel)	1500 Vrms
Isolation (channel-PLC)	1500 Vrms
Input impedance	>10 MΩ DC; 100 kΩ @ 60 Hz AC
Common-mode rejection	>130 dB @ 50/60 Hz
Normal-mode rejection	>100 dB @ 50/60 Hz
Input overvoltage	Protected to 130 Vrms AC @ 50/60 Hz or 100 VDC.
Resolution	5 µV (0.005% of FSR) typical; 14-bit minimum
Repeatability	±10 µV (±0.01% of FSR) typical
Overall accuracy	±40 µV (±0.04% of FSR) typical at 25°C ambient with 100 ppm/°C temperature coefficient
Update/sampling time	250 ms for one or all channels. Data are processed as four-sample running average providing superior repeatability. Step response time to 98% of final value < 1.5 seconds.
Upscale error reporting	Thermocouple burnout and other errors reported to PLC. Typical open probe response less than 1 minute.
Cold junction compensation	Automatic; can be calibrated independently.
Input signal wiring	12–26 AWG or 0.16–3.2 mm^2
Module power from base	2.2 W max (1.6W typical) of +5 V, and 0.01 W of –5 V
Data formatting options	Engineering units (±10000 for mV, and °C×10 or °F×10 for thermocouple); scaled integer (±32000 for mV, and 0 to 32000 for thermocouple); selection made with dipswitch on circuit board, all channels same

Index

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