IC697VTM004/008 Thermocouple

GE Fanuc Automation

Programmable Control Products

IC697VTM004 / IC697VTM008
Intelligent 4- or 8-Channel Thermocouple Board

User's Manual

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Warning notices are used in this publication to emphasize that hazardous voltages, currents, temperatures, or other conditions that could cause personal injury exist in this equipment or may be associated with its use.

In situations where inattention could cause either personal injury or damage to equipment, a Warning notice is used.

Caution

Caution notices are used where equipment might be damaged if care is not taken.

Note

Notes merely call attention to information that is especially significant to understanding and operating the equipment.

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Field Control	Motion Mate	Series Five	VuMaster
GEnet	ProLoop	Series One	Workmaster

Contents

Chapter 1 Introduction, Description, and Specifications

This manual describes the features, installation, and operation of the following Intellignet Thermocouple Boards:

Part Number	Channels
IC697VTM004	4 channels
IC697VTM008	8 channels

Reference Material and Other GE Fanuc Manuals

For a detailed explanation of the VMEbus and its characteristics, the publication “The VMEbus Specification” is available from:

VITA
VMEbus International Trade Association
7825 East Gelding Dr., No. 104
Scottsdale, AZ 85260
(480) 951-8866
FAX: (480) 951-0720
Internet: www.vita.com

The following Application and Configuration Guides are available from GE Fanuc to assist in the selection, specification, and implementation of systems based upon GE Fanuc’s products:

Analog I/O Products (Built-in-Test) Configuration Guide (catalog number GFK-2084)	Provides assistance in configuring analog I/O subsystems based on GE Fanuc’s analog I/O products, including common designs, which offer a wide variety of solutions.
Connector and I/O Cable Application Guide (catalog number GFK-2085)	Describes I/O connections that can be used with GE Fanuc’s VMEbus products. Includes connector compatibility information and examples.

General Description

The Thermocouple Board is an intelligent 4- or 8-channel low level analog input board, designed specifically for use with thermocouple inputs. The board performs reference (cold) junction temperature compensation, and provides linearization for a variety of thermocouple types. All inputs are filtered and isolated, and are protected against normal mode overvoltage. The major Thermocouple Board functional blocks are illustrated in Figure 1-1 on page 1-4. A 16-bit on-board processor controls all board functions, and performs all necessary signal processing.

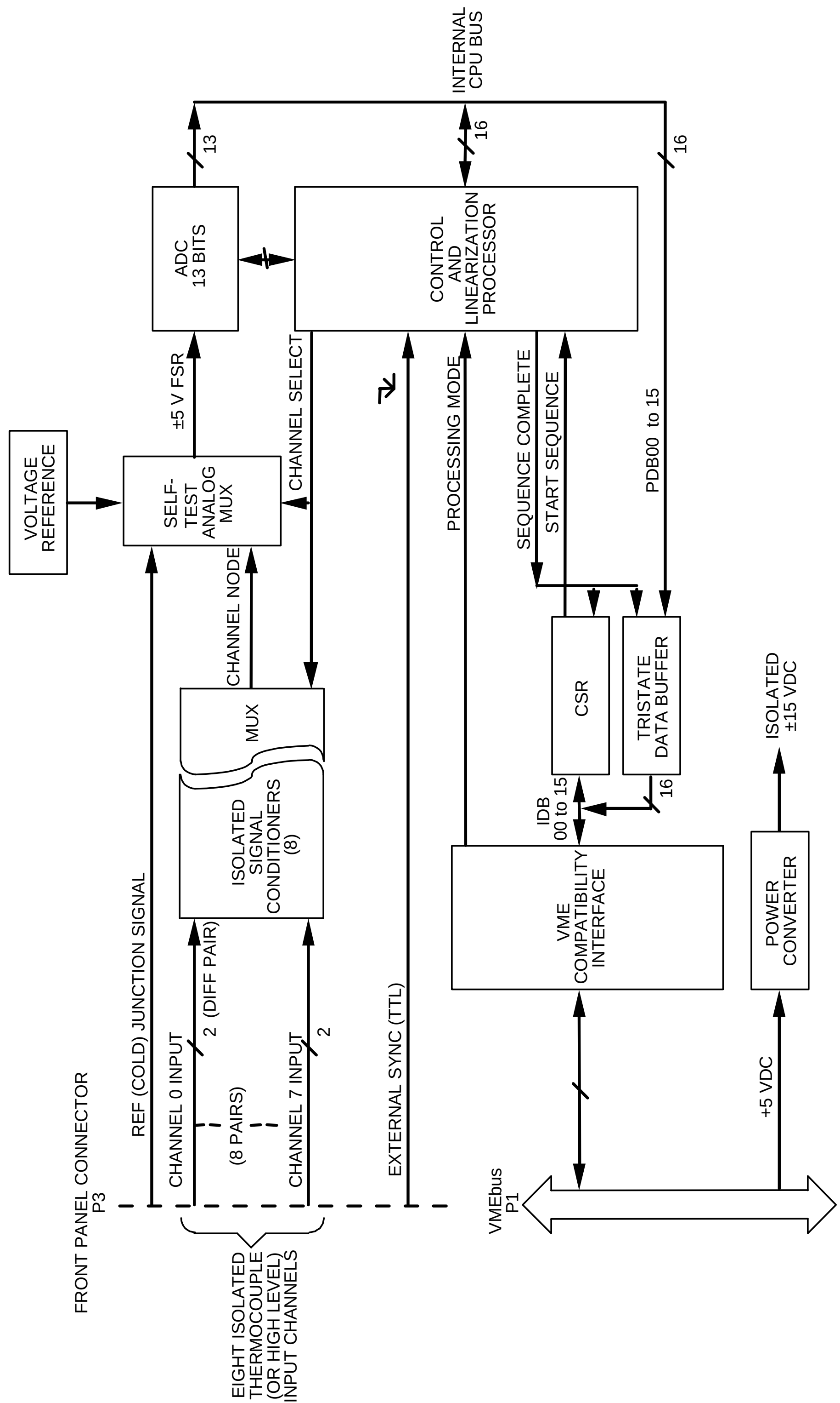
Thermocouple connections are made at a screw-terminal block which connects directly to the front panel P3 connector. Provision is also included for locating the thermocouple connections and cold junction sensor remotely. Features of the Thermocouple Board are listed below.

- Eight isolated, differential input channels
- On-board 16-bit microcomputer
- Linearization and cold junction compensation for thermocouple types J, K, T, E, R, S, B, N, and W-Re
- Accepts multiple thermocouple types simultaneously
- High CMV isolation: 1,000 V
- Dual-ported registers for minimum host overhead
- High common mode rejection: >120 dB at 60 Hz
- Local or remote cold junction compensation
- Nonvolatile storage of calibration parameters; eliminates channel adjustment potentiometers
- Analog-to-Digital Converter (ADC), 12 bits plus sign
- Inputs filtered and normal mode protected to 130 Vrms
- Terminating resistors
- Built-in-Test

Applications:

- Temperature measurement
- Industrial control systems
- Machinery Instrumentation
- Current Loop Receiver

Figure 1-1: Intelligent 8-Channel Thermocouple Board Block Diagram



Safety Summary

Warning

The following general safety precautions must be observed during all phases of this operation, service, and repair of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of this product. GE Fanuc assumes no liability for the customer's failure to comply with these requirements.

Ground the System

To minimize shock hazard, the chassis and system cabinet must be connected to an electrical ground. A three-conductor AC power cable should be used. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact to two-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet.

Do Not Operate in an Explosive Atmosphere

Do not operate the system in the presence of flammable gases or fumes. Operation of any electrical system in such an environment constitutes a definite safety hazard.

Keep Away from Live Circuits

Operating personnel must not remove product covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

Do Not Service or Adjust Alone

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

Do Not Substitute Parts or Modify System

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the product. Return the product to GE Fanuc for service and repair to ensure that safety features are maintained.

Chapter 2 Configuration and Installation

This chapter gives configuration and installation instructions for the Thermocouple Board, and is divided into the following sections:

- Physical Installation
- Before Applying Power: Checklist
- Operational Configuration
- Calibration
- Connector Descriptions

Caution

Some of the components assembled on GE Fanuc's products may be sensitive to electrostatic discharge and damage may occur on boards that are subjected to a high energy electrostatic field. Unused boards should be stored in the same protective boxes in which they were shipped. When the board is placed on a bench for configuring, etc., it is suggested that conductive material should be inserted under the board to provide a conductive shunt.

Upon receipt, any precautions found in the shipping container should be observed. All items should be carefully unpacked and thoroughly inspected for damage that might have occurred during shipment. The board(s) should be checked for broken components, damaged circuit board(s), heat damage, and other visible contamination. All claims arising from shipping damage should be filed with the carrier and a complete report sent to GE Fanuc together with a request for advice disposition of the damaged item(s).

Physical Installation

Caution

Do not install or remove boards while power is applied.

De-energize the equipment and insert the board into an appropriate slot of the chassis. While ensuring that the card is properly aligned and oriented in the supporting card guides, slide the card smoothly forward against the mating connector until firmly seated.

Before Applying Power: Checklist

Before installing the board in a VMEbus system, check the following items to ensure that the board is ready for the intended application.

- Have the chapters pertaining to theory and programming, Chapters 3 and 4, been reviewed and applied to system requirements?
- Review "Factory Installed Jumpers" on page 2-4 and Table 2-1 on page 2-5 to verify that all factory-installed jumpers are in place. To change the board address or address modifier response, refer to "Board Address and Address Modifier Selection" on page 2-4.
- Have the I/O cables, with the proper mating connectors, been connected to the input connector P3? Refer to "Connector Descriptions" on page 2-12 for connector descriptions.
- Calibration has been performed at the factory. If recalibration is required, refer to "Calibration" on page 2-8.

After the checklist above has been completed, the board can be installed in a VMEbus system. **DO NOT** install or remove the board with power applied. This board may be installed in any slot position, except slot one which is usually reserved for the master processing unit.

Caution

Do not install or remove this board with power applied to the system.

Operational Configuration

Control of the Thermocouple Board address and I/O access mode are determined by field replaceable, on-board jumpers. This section describes the use of these jumpers, and their effects on board performance. The locations and functions of all Thermocouple Board jumpers are shown in Figure 2-1 on page 2-7 and Table 2-1 on page 2-5.

Factory Installed Jumpers

Each Thermocouple Board is configured at the factory with the specific jumper arrangement shown in Table 2-1 on page 2-5. The factory configuration establishes the following functional baseline for the Thermocouple Board, and ensures that all essential jumpers are installed.

- Board short address is set at 0000 HEX
- I/O ACCESS MODE is short supervisory

Board Address and Address Modifier Selection

Address jumper headers J12 and J13 permit the Thermocouple Board to be located on any 16-bit word boundary within the short I/O address space available on the VMEbus. The space needed by this board requires 15 address lines be decoded to account for all of the board’s address locations. Four of these lines are used to decode the on-board functions (Chapter 3). Thus, the board’s base address is defined by the remaining 11 address lines, bits A05 through A15.

The board address is programmed by installing shorting plugs at all “zero” or LOW address bit positions in jumper blocks J12 and J13, and by omitting the shorting plugs at the “one” or HIGH positions. Address bit A05 has a weight of 32 byte locations. As an example, the typical jumper arrangement shown in Table 2-2 on page 2-8 would produce a short I/O board address of 8F80 HEX.

I/O ACCESS MODE is programmed by selecting the state of the address modifier AM2 with jumper J13-AM2. Short supervisory access is selected by omitting the jumper. Short nonprivileged access is selected by installing the jumper.

Table 2-1: Programmable Jumper Functions

Jumper ID	Function (Installed)	Fact Config	Field Alterable
J12-A15	Board Address Bit A15 = 0	Installed	Yes
J12-A14	Board Address Bit A14 = 0	Installed	Yes
J12-A13	Board Address Bit A13 = 0	Installed	Yes
J12-A12	Board Address Bit A12 = 0	Installed	Yes
J12-A11	Board Address Bit A11 = 0	Installed	Yes
J12-A10	Board Address Bit A10 = 0	Installed	Yes
J12-A09	Board Address Bit A09 = 0	Installed	Yes
J12-A08	Board Address Bit A08 = 0	Installed	Yes
J13-A07	Board Address Bit A07 = 0	Installed	Yes
J13-A06	Board Address Bit A06 = 0	Installed	Yes
J13-A05	Board Address Bit A05 = 0	Installed	Yes
J13-AM2	Short Nonprivileged Access	Omitted	Yes
J11-Top	CAL Enable	Omitted	Yes
J11-Bottom	CAL Disable	Installed	Yes
J10-Right *	Channel 0, 60 mV range [50 mV]	Installed	Yes
J10-Left *	Channel 0, 30 mV range [5 mV]	Omitted **	Yes
J9-Right	Channel 1, 60 mV range [50 mV]	Installed	Yes
J9-Left	Channel 1, 30 mV range [5 mV]	Omitted **	Yes
J8-Right	Channel 2, 60 mV range [50 mV]	Installed	Yes
J8-Left	Channel 2, 30 mV range [5 mV]	Omitted **	Yes
J7-Right	Channel 3, 60 mV range [50 mV]	Installed	Yes
J7-Left	Channel 3, 30 mV range [5 mV]	Omitted **	Yes
J4-Right	Channel 4, 60 mV range [50 mV]	Installed	Yes
J4-Left	Channel 4, 30 mV range [5 mV]	Omitted **	Yes
J3-Right	Channel 5, 60 mV range [50 mV]	Installed	Yes
J3-Left	Channel 5, 30 mV range [5 mV]	Omitted **	Yes
J2-Right	Channel 6, 60 mV range [50 mV]	Installed	Yes
J2-Left	Channel 6, 30 mV range [5 mV]	Omitted **	Yes
J1-Right	Channel 7, 60 mV range [50 mV]	Installed	Yes
J1-Left	Channel 7, 30 mV range [5 mV]	Omitted **	Yes
J5	External Trigger Input Enabled ****	Omitted	Yes
J6-Right ***	Local CJC Sensor Enabled	Installed	Yes
J6-Left ***	Remote CJC Sensor Input Enabled	Omitted	Yes

* Omitting the 30/60 mV range jumper entirely produces a channel range of ±90 mV/full scale. All orientations listed assumes the board is oriented as shown in Figure 2-1 on page 2-7, which shows the configuration listed in this table. Figures in brackets ([]) apply to the High-Level board configuration.

** High-level board range jumpers are configured for the ±5 V range (left jumper installed, right jumper omitted).

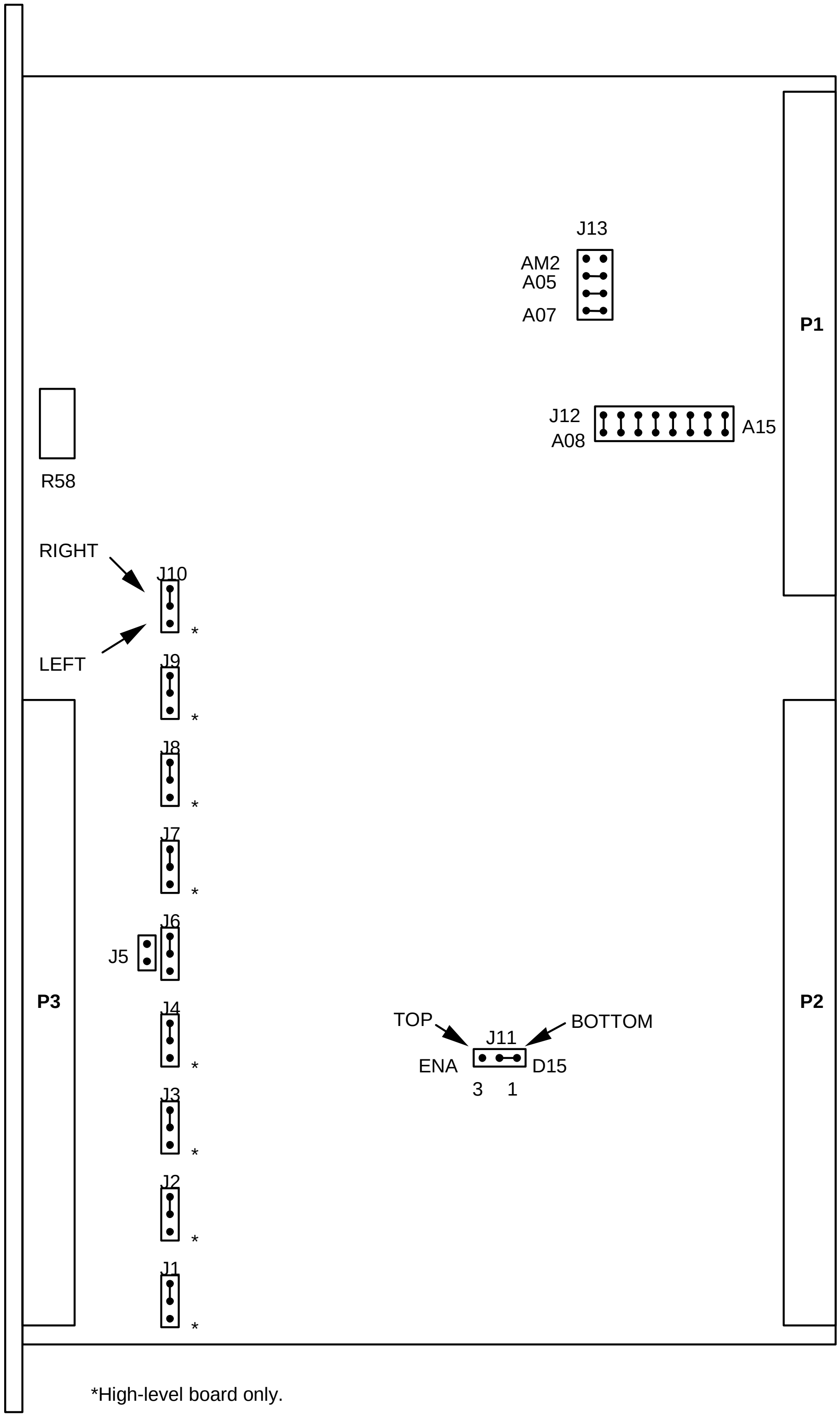
*** For high-level boards, J6-Right is always shorted; J6-Left has no function.

**** If installing J5, J5-Right must be installed. External trigger and Remote CJC cannot be used simultaneously (see “Remote Initiation” on page 3-11).

Analog Input Configuration

Each input channel may be jumper programmed for one of three millivoltage ranges. Factory installed jumpers, shown in Table 2-1 on page 2-5, configure all input ranges to the ±60 mV full scale range. All analog inputs enter the board via the front panel connector P3, and are described further in “Connector Descriptions” on page 2-12.

Figure 2-1: Thermocouple Board Jumper Locations



*High-level board only.

Calibration

Before delivery from the factory, the Thermocouple Board is fully calibrated and conforms to all applicable specifications. Should recalibration be required, refer to “Equipment Required” below, “Internal Reference Calibration Procedure” and “Channel Offset and Gain Calibration Procedure” on page 2-10, and “Cold Junction Calibration (Thermocouple Board Only)” on page 2-11. Perform the indicated calibration procedures in the order shown. The locations of all adjustments and testpoints are shown in Figure 2-2 on page 2-9.

As delivered from the factory, the single calibration adjustment is sealed against accidental movement. However, the seal is easily broken for re-calibration. The adjustment should be resealed after recalibration has been completed.

Equipment Required

Digital Voltmeter (DVM)	±1.000 VDC and ±10.000 VDC ranges; five or more digits; ±0.01 percent of reading measurement accuracy; 10 Megohm minimum input impedance.
Digital Voltage Source	±100.000 mVDC and ±0.010 mVDC voltage source (±10.000 VDC ±0.001 VDC for high level board). Adjustable to 30.00 mVDC, 60.00 mVDC, and 90.00 mVDC (50 mVDC and 5.000 VDC for a high level board).
Cardcage	VMEbus backplane or equivalent, J1 connector, CPU, +5 ±0.1 VDC, 3 Amp (Reserve current) power supply. One slot allocated for testing the Thermocouple Board.
Extender card	VMEbus extender card.

Caution

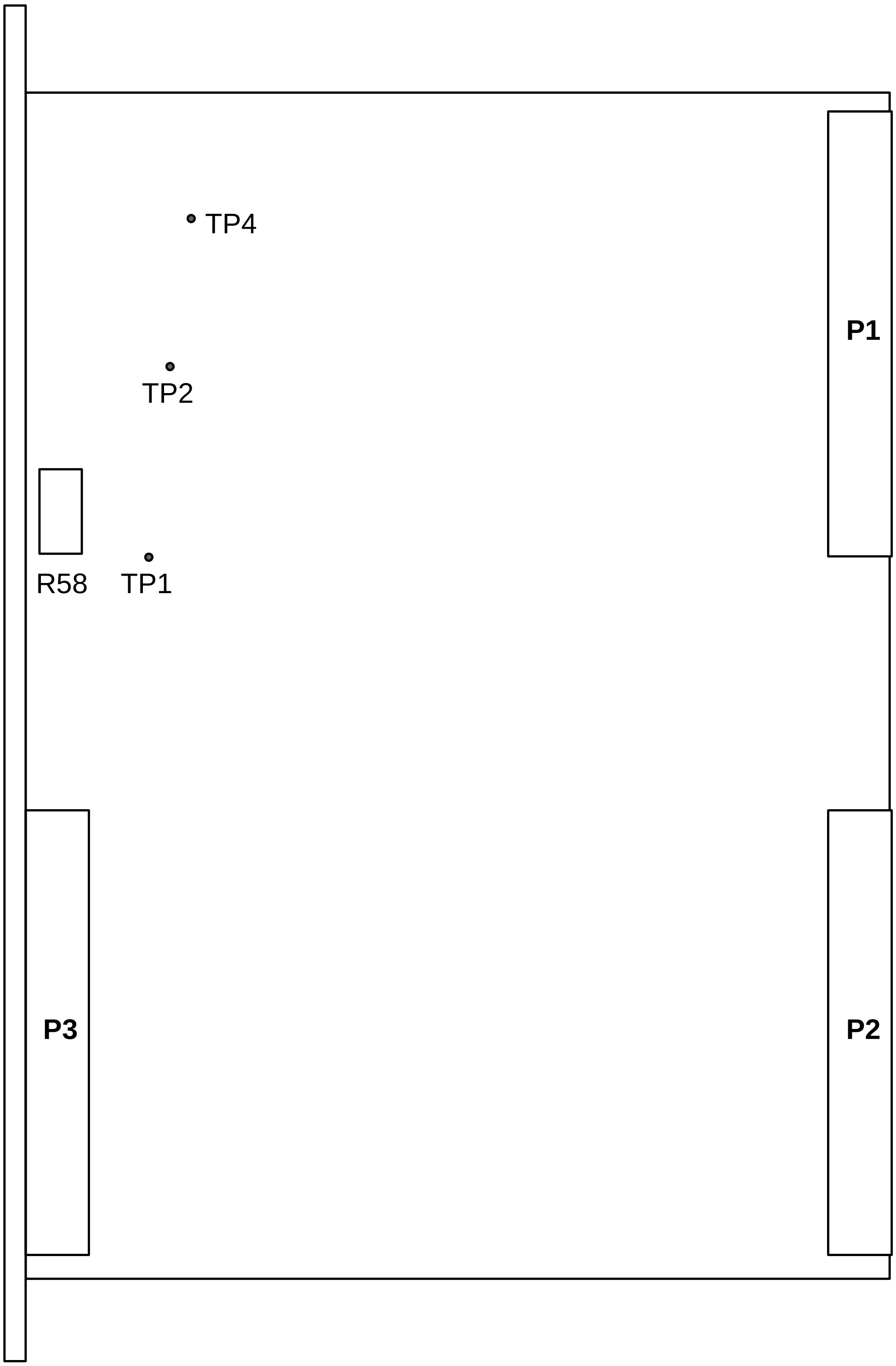
Do not install or remove this board with power applied to the system.

Table 2-2: Typical Board Address (8F80 HEX) Selection

Address Jumper Blocks J12 and J13		
Position	**ADDR Bit**	**State ***
J13-A05	A05	Shorted
J13-A06	A06	Shorted
J13-A07	A07	Open
J12-A08	A08	Open
J12-A09	A09	Open
J12-A10	A10	Open
J12-A11	A11	Open
J12-A12	A12	Shorted
J12-A13	A13	Shorted
J12-A14	A14	Shorted
J12-A15	A15	Open

* Shorted = “zero” (0)
Open = “one” (1)

Figure 2-2: Thermocouple Board Test Points and Adjustments Locations



Internal Reference Calibration Procedure

1. Install the Thermocouple Board on an extender card in a VMEbus backplane.
2. Apply power to the backplane. Allow a minimum warmup interval of ten minutes after power has been applied before proceeding.
3. Connect the digital voltmeter between TP1 (VREF) (+) and TP-4 (HQR) (-).
4. Adjust potentiometer R58 for a digital voltmeter indication of +5.000 VDC ±0.005 VDC.
5. Calibration of the Thermocouple Board internal reference is completed.

Channel Offset and Gain Calibration Procedure

Channel offset and gain correction factors for the eight input channels are calculated automatically by executing processing sequences while operating the board in the OFFSET or GAIN CALIBRATION MODES. The correction factors are stored in nonvolatile memory for subsequent use in normal measurement sequences.

Calibration of each channel consists of the following operations, performed in the order shown. CCR default values can be retained, with the possible exception of active channel selection:

1. Initiate continuous scanning (CSR = 0083 H), and wait at least one minute before proceeding.
2. Move the CAL ENABLE/DISABLE jumper to the ENABLE position.
3. Establish a zero input condition (0.000 mVDC) for the channel to be zero calibrated. Initiate a processing sequence in the SINGLE SCAN MODE (CSR = 81 HEX), and wait for a return code of 0080H within 10 seconds.
4. Initiate a processing sequence in the CHANNEL OFFSET CALIBRATION MODE (CSR = 0089 HEX), using the Channel Control Register (CCR) channel mask to select the channel under calibration. (Refer to “Channel Control” on page 3-12 for a description of the CCR). Completion of the offset calibration sequence is indicated when the SEQUENCE COMPL L flag in the STATUS Register is cleared (CSR = 0088H), and will occur within 10 seconds of initiation.

   Note

   Each channel must be calibrated for all three ranges by loading a hexadecimal “D” (30 mV), “E” (60 mV), or “F” (90 mV) into the associated response select register, as shown in Table 3-6 on page 3-17.

5. Establish a positive full scale input condition for the channel under calibration (e.g., +30.00 mVDC for the ±30 mVDC range). Initiate a single scan sequence (CSR = 81 HEX).
6. Initiate a processing sequence in the CHANNEL GAIN CALIBRATION MODE (CSR = 008B HEX), using the CCR channel mask to select the channel under calibration. Completion of the Gain Calibration sequence is indicated when the SEQUENCE COMPL L flag in the STATUS Register is cleared (CSR = 008A H)

7. Repeat steps 2 through 5 for all ranges on all channels.
8. Calibration is completed. Remove all test connections.
9. After all channels have been calibrated, the CAL DISABLE jumper **must** be relocated to the DISABLE position before power is removed.
10. Remove power.

Note

If all millivolt channels are jumpered for the same gain, the inputs can be calibrated simultaneously by connecting all of the inputs together (hi to hi, and lo to lo), and using a CCR channel mask value of FF (HEX). RTD channels require individual, isolated resistors for calibration.

Cold Junction Calibration (Thermocouple Board Only)

Note

Cold junction calibration is performed at the factory; re-calibration should not be required unless the cold junction sensor on the board is replaced.

Like the offset and gain calibration operations, the Cold Junction Calibration is performed automatically, and is based upon a known input condition. The input condition in this case consists of the temperature of the cold junction sensor, which must be measured with an accuracy of ±0.5°F.

The measured sensor temperature is loaded by the VMEbus processor into the Cold Junction Data Register, in degrees-Rankine times 100 after initiating and completing a single scan. For example, if the sensor temperature is 64.5°F, the Cold Junction Register must be loaded with 52,420 [100 x (64.5 + 459.7)], or CCC4 (HEX)**.** Then, with the CAL ENABLE/DISABLE jumper in the ENABLE position, a process is initiated in the COLD JUNCTION CALIBRATION MODE. The cold junction channel calibration will proceed automatically. After calibration is completed (SEQUENCE COMPL L flag cleared), the CAL ENABLE/DISABLE jumper must be replaced in the DISABLE position before power is removed.

Note

If the calibration procedure requires more than 15 minutes for completion, repeat step 1 every 15 minutes to minimize short term drift.

Connector Descriptions

Two 96-pin DIN connectors, (Figure 4-2 on page 4-7), connect the Thermocouple Board to the VMEbus backplane. P1 contains the address, data and control lines, and all additional signals necessary to control VMEbus functions related to the board.

Thermocouple (or millivolt) signal inputs (high level inputs for the high level board) are received by front-panel connector P3, which is designed to accept a 20-station screw-terminal plug connector, as shown in Figure 2-3 on page 2-13. The separate screw plug connector permits thermocouple connections to be made with screw terminals, without consequently wiring the Thermocouple Board into the system harness. A screw plug connector is supplied with each Thermocouple Board. Replacement connectors are readily available. Pin configuration and signal pin assignments for P3 are shown in Figure 2-4 on page 2-14 and Table 2-3 on page 2-15, respectively.

Various thermocouple types and low level linear inputs may be mixed in any combination among the eight available input channels. However, the correct gain must be jumper-selected for each channel, as shown in Table 3-6 on page 3-17 and Table 2-1 on page 2-5.

Pin 9 in the P3 connector is connected to signal ground, and may be used for shield drain connections *if the shields are protected from high potentials***.** Due to the isolated nature of the signal inputs however, the HI/LO input lines can withstand potentials up to 1,000 Peak Volts.

The Thermocouple Board responds to very low level signals. Avoid locations directly adjacent to VME boards that may generate high energy or high frequency electrical fields.

Figure 2-3: Thermocouple Board Front Panel Thermocouple Connections

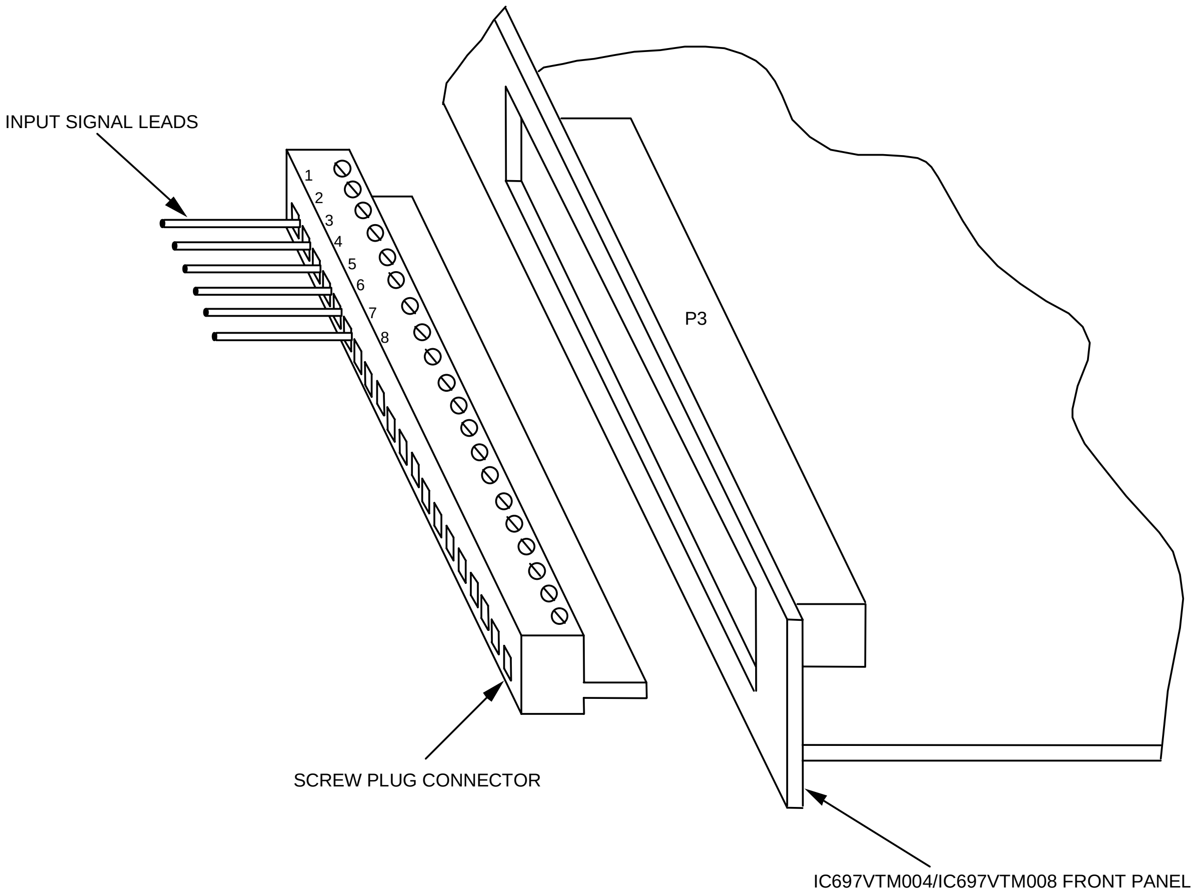


Figure 2-4: P3 Connector Pin Configuration

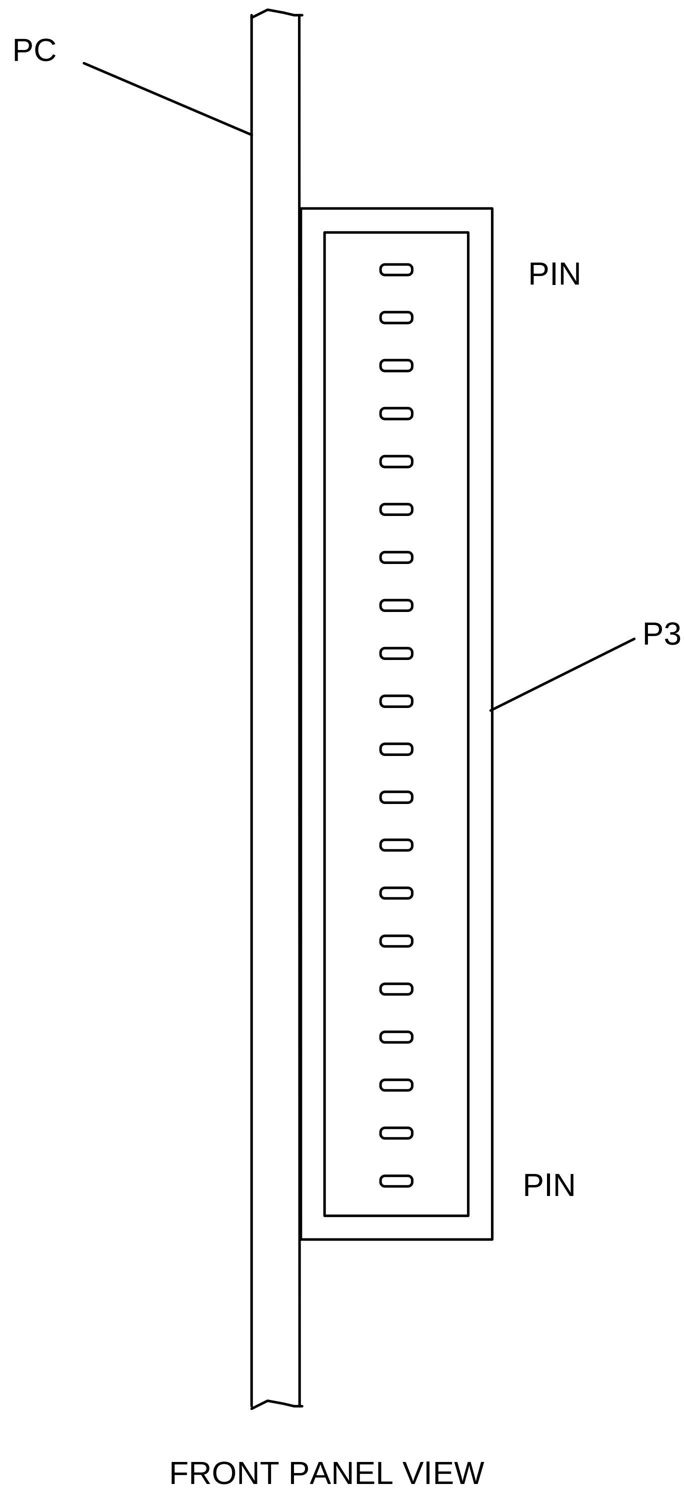


Table 2-3: Thermocouple Board P3 Connector Signal Assignments

P3 Pin Number *	Signal Name
1	INPUT CHANNEL 0 HI
2	INPUT CHANNEL 0 LO
3	INPUT CHANNEL 1 HI
4	INPUT CHANNEL 1 LO
5	INPUT CHANNEL 2 HI
6	INPUT CHANNEL 2 LO
7	INPUT CHANNEL 3 HI
8	INPUT CHANNEL 3 LO
9	ANALOG GROUND
10	REMOTE SENSOR EXCITATION
11	REMOTE SENSOR/TRIG SIGNAL **
12	REMOTE SENSOR/TRIG RETURN
13	INPUT CHANNEL 4 HI
14	INPUT CHANNEL 4 LO
15	INPUT CHANNEL 5 HI
16	INPUT CHANNEL 5 LO
17	INPUT CHANNEL 6 HI
18	INPUT CHANNEL 6 LO
19	INPUT CHANNEL 7 HI
20	INPUT CHANNEL 7 LO

* P3 pin numbers are identical to terminal numbers on the mating screw-terminal connector block.

** Pin 11 is jumper-selectable for remote input of either a temperature sensor or a synch (trigger) signal. For External Trigger, Jumper J5 and J6-Right must be installed.

Chapter 3 Programming

This chapter gives programming instructions for the Thermocouple Board, and is divided into the following sections:

- Introduction to Controlling the Thermocouple Board
- Control and Status Register Descriptions
- Board Identification Register
- Board Address and Access Mode
- Board Initialization
- Processing Sequence
- Sequence Initiation and Monitoring
- Channel Control
- Thermocouple Type Selection
- Operating Modes
- Built-in-Test
- Program Examples

Introduction to Controlling the Thermocouple Board

Communication with the Intelligent 8-Channel Thermocouple Input Board takes place through 16 contiguous, 16-bit registers which are mapped into the VMEbus short I/O address space. All registers are listed in Table 3-1 on page 3-7, and are described in detail throughout this chapter.

Control and Status Register Descriptions

Control and Status Register (CSR) functions are common to all channels, and are summarized in Table 3-1 and Table 3-2 on page 3-7. The CSR provides control and monitoring of the following board operations:

- Processing Mode
- Channel Control
- Board RESET
- Local Built-in-Test (BIT) status
- Front panel FAIL indication

Board Identification Register

The Board Identification Register (BIR) contains the board identification code (0600 HEX) for the Thermocouple Board.

Board Address and Access Mode

On-board programmable address jumpers permit the Thermocouple Board to be located on any *16-word* boundary within the VME short address space. Access mode may be either short supervisory or short nonprivileged. Selection of board address and access mode is described in detail in Chapter 2.

Board Initialization

When SYSTEM RESET is applied to the board, Built-in-Test (BIT) is executed and the board is initialized to the following default state:

- Thermocouple Board
  - (1) Continuous scanning of all eight channels
  - (2) Type K thermocouple selected
  - (3) Degrees F, resolution 1 degree
  - (4) Two’s complement coding of data
  - (5) Internal triggering
  - (6) FAIL indicator ON
- High Level Board
  - (1) Continuous scanning of all eight channels
  - (2) High Range (±5 V)
  - (3) 1 mV resolution
  - (4) Two’s complement coding of data
  - (5) Internal triggering
  - (6) FAIL indicator ON

BIT can be initiated also by setting the SOFTWARE RESET control bit HIGH for a minimum of 2 microseconds. Within 20 microseconds after SOFTWARE RESET falls LOW, the FAILED INT BIT flag is set automatically and the on-board BIT is executed (see “Built-in-Test”). The final state of the FAILED INT BIT flag is valid when SEQ COMPL falls LOW. After a reset operation has occurred, all nondefault channel control parameters must be loaded into Channel Control Registers (see “Channel Control”).

Note

Logic State Convention - To avoid ambiguities in references to logic levels, this document uses the convention that a data bit or control line is “set” when it is in the “one”, or high state, and is “clear” when in the “zero” or low state.

Table 3-1: Thermocouple Board Register Map

Address		Register Function	Access Mode
Hex	DEC		
00	000	BOARD IDENT	READ
02	002	CONTROL/STATUS	READ/WRITE
04	004	ERROR REGISTER	READ/WRITE
06	006	(RESERVED)	READ/WRITE
08	008	CHANNEL CONTROL	READ/WRITE
0A	010	RESPONSE SELECT 0 TO 3	READ/WRITE
0C	012	RESPONSE SELECT 4 TO 7	READ/WRITE
0E	014	COLD JUNCTION DATA	READ/WRITE *
10	016	CONVERTED DATA 0	READ
12	018	CONVERTED DATA 1	READ
14	020	CONVERTED DATA 2	READ
16	022	CONVERTED DATA 3	READ
18	024	CONVERTED DATA 4	READ
1A	026	CONVERTED DATA 5	READ
1C	028	CONVERTED DATA 6	READ
1E	030	CONVERTED DATA 7	READ

* The Cold Junction Data Register accepts a D16 data transfer from the VMEbus during calibration; active only for thermocouple board.

Table 3-2: Thermocouple Board Control Register Functions

Control Register (Relative Address $02)							
Bit D15	**Bit D14**	**Bit D13**	**Bit D12**	**Bit D11**	**Bit D10**	**Bit D09**	**Bit D08**
Reserved							
Bit D07	**Bit D06**	**Bit D05**	**Bit D04**	**Bit D03**	**Bit D02**	**Bit D01**	**Bit D00**
FAIL LED L	Reserved	SOFTWARE RESET H	ENABLE EXT TRIG H	MODE A2 H	MODE A1 H	MODE A0 H	START SEQUENCE H

Control Register Bit Definitions

Bits D15 through D08: **Reserved** – Control bits D08 through D15 currently have no effect on the operation of the board, and should be written to the CSR as low (zero) logic levels.

Bit D07: **Fail LED Low (FAIL LED L)** – OFF if this bit is set to “one,” and ON if the bit is “zero”.

Bit D06: **Reserved** – No active control function.

Bit D05: **Software reset High (SOFTWARE RESET H) –** When set to "one", resets the on-board processor. The processor will remain reset until this bit is cleared to "zero."

Bit D04: **Enable external trigger High (ENABLE EXT TRIG H) –** When set to "one," the mode-selected operation will be initiated by a remote EXT TRIG H signal at the P2 connector.

Bits D03 through D01: **Operating Mode (MODE A[2-0]H) –** D03, D02, and D01 control the operating mode as:

D03	D02	D01	Operating Mode
0	0	0	Single Scan
0	0	1	Continuous Channel Scan
0	1	0	Reserved
0	1	1	Reserved
1	0	0	Channel Offset Calibration
1	0	1	Channel Range Calibration
1	1	0	Cold Junction Calibration
1	1	1	Reserved

Bit D00: **Start Sequence High (START SEQUENCE H)** – Initiates a processing sequence in the mode determined by Bits 03, 02, and 01, and clears the SEQUENCE COMPLETE L flag in the Status Register.

Table 3-3: Thermocouple Board Status Register Functions

Status Register (Relative Address $02)							
Bit D15	**Bit D14**	**Bit D13**	**Bit D12**	**Bit D11**	**Bit D10**	**Bit D09**	**Bit D08**
Reserved							

Bit D07	Bit D06	Bit D05	Bit D04	Bit D03	Bit D02	Bit D01	Bit D00
FAIL LED L *	FAILED INT BIT H	SOFTWARE RESET *	ENABLE EXT TRIG H *	MODE A2 H *	MODE A1 H *	MODE A0 H *	SEQUENCE COMPL L

Status Register Bit Definitions

Bits D15 through D08: **Reserved –** Control bits 15 through 8 currently have no effect on the operation of the board, and should be written to the CSR as low (zero) logic levels.

Bit D07: **Fail LED Low (FAIL LED L) –** OFF if this bit is set to "one," and is ON if the bit is "zero".

Bit D06: **Reserved –** No active control function.

Bit D05: **Software Reset (SOFTWARE RESET) –** When set to “one”, resets the on-board processor. The processor will remain reset until this bit is cleared to “zero.”

Bit D04: **Enable External Trigger High (ENABLE EXT TRIG H) –** When set to “one,” the mode-selected operation will be initiated by a remote EXT TRIG H signal at the P2 connector.

Bit D03 through D01: **Operating Mode (MODE A[2-0]H) –** D03, D02, and D01 control the operating mode as:

D03	D02	D01	Operating Mode
0	0	0	Single Scan
0	0	1	Continuous Channel Scan
0	1	0	Reserved
0	1	1	Reserved
1	0	0	Channel Offset Calibration
1	0	1	Channel Range Calibration
1	1	0	Cold Junction Calibration
1	1	1	Reserved

Bit D00: **Sequence Compete Low (SEQUENCE COMPL L) –** when asserted (HIGH), this bit indicates that either a processing sequence, a RESET operation, or Built-in-Test (BIT) is in progress. This bit is cleared to “zero” when all on-board operations have been completed..

* The corresponding control register bit is mapped directly to this flag.

Processing Sequence

A processing sequence digitizes the signals present at the inputs of all *enabled* channels (see "Channel Control"), and converts the digital codes into temperature data in the Converted Data Registers. When a sequence is initiated, all enabled channels are processed in order, starting with Channel 0 and proceeding through Channel 7. During a processing sequence, each enabled channel signal is:

- Digitized into a 13-bit binary code
- Corrected for offset and gain errors
- Corrected for reference (cold) junction temperature (TC channels)
- Linearized for program-specified thermocouple type (TC channels)
- Scaled to program-specified units and resolution
- Converted into program-specified output data code
- Transferred to the associated Converted Data Register for access by the VMEbus

The cold junction temperature is measured once during each channel scan, and the result is filtered to produce a stable reference temperature.

Sequence Initiation and Monitoring

Local (CSR) Initiation

Setting the Control Register START SEQUENCE H bit (D0) initiates a processing sequence and simultaneously sets the Status Register SEQUENCE COMPL L flag (D0) to “one.” The SEQUENCE COMPL L flag remains set until the sequence has been completed, after which the flag is cleared to “zero.” Access to Channel Control and Data Registers is allowed while SEQUENCE COMPL L is set, although arbitration delays may extend the access time while the flag is high.

Note

The scan mode should not be altered while the start sequence bit is set.

Remote Initiation

If Control Register bit D4 is set, scan initiation will occur on the falling edge of the EXT TRIG signal from the P3 input connector. This feature permits synchronization of measurements with an external event, such as zero crossing of the power line voltage. Remote initiation normally is used in the single scan operating mode (see “Operating Modes”). For Remote Initiation, jumper J5 must be installed and jumper J6 must be placed in the right position (see Figure 2-1 on page 2-7 for reference). Remote CJC cannot be used with Remote Initiation.

Channel Control

Control parameters that are common to all input channels are controlled by the Channel Control Register (CCR). The following parameters are established by the CCR:

- Channel enable/disable
- Converted data coding
- Data units
- Data resolution (output LSB weight)

The individual bit functions within a CCR are summarized in Table 3-4 below. Thermocouple types are channel-specific, and are selected with the RESPONSE SELECT Registers described in the "Thermocouple Type Selection" on page 3-15.

Table 3-4: Thermocouple Board Channel Control Register Functions

Channel Control Word Format (Relative Address $08)							
Bit D15	**Bit D14**	**Bit D13**	**Bit D12**	**Bit D11**	**Bit D10**	**Bit D09**	**Bit D08**
DATA CODE A1 H	DATA CODE A0 H	LINEAR RESOLUTION A1 H	LINEAR RESOLUTION A0 H	TEMP UNITS A1 H	TEMP UNITS A0 H	RESOLUTION A1 H	RESOLUTION A0 H
Bit D07	**Bit D06**	**Bit D05**	**Bit D04**	**Bit D03**	**Bit D02**	**Bit D01**	**Bit D00**
ENABLE CHAN 7 H	ENABLE CHAN 6 H	ENABLE CHAN 5 H	ENABLE CHAN 4 H	ENABLE CHAN 2 H	ENABLE CHAN 2 H	ENABLE CHAN 1 H	ENABLE CHAN 0 H

Channel Control Bit Definitions

Bits D15 through D14: **DATA CODE A[1-0]H**

D15	D14	Data Code
0	0	Offset Binary
0	1	Two's Complement
1	0	Complement of Offset Binary
1	1	Complement of Two's Complement

Bits D13 through D12: **LINEAR RESOLUTION A[1-0]H**

D15	D14	Output LSB Weight (mV)*
0	0	0.01
0	1	0.1
1	0	1.0
1	1	Reserved

Bits D11 through D10: **TEMP UNITS A[1-0]H –** D11 and D10 establish the processed temperature units as:

D11	D10	Units
0	0	Degrees Fahrenheit
0	1	Degrees Rankine
1	0	Degrees Celsius
1	1	Degrees Kelvin

Bits D09 through D08: **RESOULTION A[1-0]H –** D09 and D08 control data scale resolution as:

D09	D08	Output LSB Weight (Degrees)*
0	0	0.1
0	1	1
1	0	10
1	1	Reserved

Bits D07 through D00: **ENABLE CHAN –** D07 through D00 constitute a channel-enable mask.

* Actual resolution is limited by 13-bit quantizing. Refer to 3-2 on page 3-7.

Channel Selection

CCR bits D7 through D0 constitute a channel-enable mask, with each bit controlling the corresponding input channel. A channel is enabled if the associated mask bit is “one”, and is disabled (not processed) if the bit is “zero”. The default is FF HEX (all channels enabled). This feature produces the maximum scanning rate by eliminating the time required for processing unused channels.

Cold junction temperature can be monitored directly by reading the Cold Junction Data Register. This register contains the temperature of the P3 connector on the board, and represents the ambient temperature in degrees Rankine x100 at that point.

Data Access and Coding

Processed data is presented in the Converted Data Registers in 16-bit hexadecimal format. As Table 3-4 on page 3-7 shows, CCR bits D15 and D14 select data encoding as two’s complement, offset binary, or the complements of these formats. Data access and coding defined in the CCR applies to all enabled channels.

The processed temperature or millivolt data for each channel is retrieved by reading the associated 16-bit Converted Data Register (CDR). Data format for the Converted Register is shown in Table 3-5 on page 3-14.

Table 3-5: Thermocouple Board Converted Word Data

Relative Address $10 through $1E							
Bit D15	**Bit D14**	**Bit D13**	**Bit D12**	**Bit D11**	**Bit D10**	**Bit D09**	**Bit D08**
MSB							
Bit 07	**Bit 06**	**Bit 05**	**Bit 04**	**Bit 03**	**Bit 02**	**Bit 01**	**Bit 00**
							LSB

Resolution and Units

CCR bits D9 and D8 establish the temperature data resolution (Table 3-4 on page 3-7) of the data in the *CDRs*, for the *thermocouple channels*. Resolution of the *linear channels* is controlled by CCR bits D13 and D12. D11 and D10 select the temperature units. Control bits D11 through D8 have no effect on channels where a linear voltage scale has been selected.

Note

Usable resolution is limited by 13-bit quantizing of inputs.

Thermocouple Type Selection

The two RESPONSE SELECT Registers contain the 4-bit codes that select the thermocouple types for all eight input channels. The thermocouple types available for the Thermocouple Board are listed in Table 3-6 on page 3-17. The 4-bit select code and voltage range that are required for each type are indicated in the Table 3-6 on page 3-17 in addition to the location of the select code for each input channel within the two RESPONSE SELECT Registers.

Voltage ranges are jumper-selected on the board, and must match the ranges indicated in Table 3-6 on page 3-17 for each channel thermocouple type or millivolt range.

High-Level Range Selection

For High Level Boards, input range is selected as ±5 V with response type = 1, and ±50 mV with response type = 0.

Operating Modes

CSR bits D3, D2, and D1 establish the PROCESSING MODE, as indicated in Table 3-2 on page 3-7. Further refinement of the processing parameter is controlled through the CCR and the two RESPONSE SELECT registers listed in Table 3-1 on page 3-7. The characteristics of each operating mode are described in this section.

Single Scan

Sequence initiation in the SINGLE SCAN MODE causes a single scan of all enabled channels to occur, after which the SEQUENCE COMPL flag in the Status Register is cleared to “zero”.

Continuous Channel Scan

In this mode all enabled channels are scanned continuously without intervention from the VMEbus. After the first complete channel scan has taken place, the SEQUENCE COMPL L flag is cleared to “zero”.

Channel Offset and Gain Calibration

Channel offset and gain correction factors for the eight input channels are calculated automatically by executing processing sequences while operating the board in the OFFSET or GAIN calibration modes. The correction factors are stored in nonvolatile memory for subsequent use in normal measurement sequences. Refer to “Channel Offset and Gain Calibration Procedure” on page 2-10 for a detailed description of offset and gain calibration.

Table 3-6: Thermocouple Type Selection

Thermocouple Type	Alloy	Voltage Range	Selection Code (HEX)
B	Pt–6%Rh vs Pt-30%Rh (Platinum – Rhodium)	±30 mV	0
E	Chromel – Constantan	±90 mV	1
J	Iron – Constantan	±60 mV	2
K	Chromel – Alumel	±60 mV	3
N	Nicrosil – Nisil	±60 mV	4
R	Pt vs Pt-13%Rh	±30 mV	5
S	Pt vs Pt-10%Rh	±30 mV	6
T	Copper – Constantan	±30 mV	7
–	W vs W-26%Re (Tungsten – Rhenium)	±60 mV	8
–	W-5%Re vs W-26%Re	±60 mV	9
–	W-3%Re vs W-25%Re	±60 mV	A
–	(Reserved)	–	B
–	(Reserved)	–	C
–	Linear Conversion	±30 mV	D
–	Linear Conversion	±60 mV	E
–	Linear Conversion	±90 mV	F

* High level board (See “High-Level Range Selection” on page 3-15)

Relative Address $0A							
Bit D15	**Bit D14**	**Bit D13**	**Bit D12**	**Bit D11**	**Bit D10**	**Bit D09**	**Bit D08**
Channel 3				Channel 2			
Selection Code				Selection Code			

Bit D07	Bit D06	Bit D05	Bit D04	Bit D03	Bit D02	Bit D01	Bit D00
Channel 1				Channel 0			
Selection Code				Selection Code			

Relative Address $0C							
Bit D15	**Bit D14**	**Bit D13**	**Bit D12**	**Bit D11**	**Bit D10**	**Bit D09**	**Bit D08**
Channel 7				Channel 6			
Selection Code				Selection Code			

Bit D07	Bit D06	Bit D05	Bit D04	Bit D03	Bit D02	Bit D01	Bit D00
Channel 5				Channel 4			
Selection Code				Selection Code			

Cold Junction Calibration

Like the offset and gain calibration operations, the cold junction calibration is performed automatically, and is based upon a known input condition. The input condition in this case, however, consists of the temperature of the cold junction sensor, which must be measured with an accuracy of ± 0.5°C.

The measured sensor temperature is loaded by the VMEbus processor into the Cold Junction Data Register in degrees-Rankine times 100. Refer to “Cold Junction Calibration (Thermocouple Board Only)” on page 2-11 for a detailed description of cold junction calibration.

Built-In-Test

The on-board processor executes an internal Built-in-Test (BIT) when a reset operation occurs (see “Board Initialization”). The status register flag FAILED INT BIT (D6) will be set when BIT is initiated, and will be cleared after all on-board functions pass BIT. Failure of BIT is indicated if the SEQUENCE COMPL L flag is cleared while the FAILED INT BIT H flag is set. Total time required for BIT is approximately one second. Board functions that are monitored by BIT include are summarized in Table 3-7 on page 3-20.

Note

An open thermocouple input will cause a negative off-scale indication.

Failure of BIT will not disable the Thermocouple Board. The FAILED INT BIT H flag should be verified after each reset operation, however, to ensure that the board and its inputs are functioning properly. If BIT should ever fail, compare the value in the ERROREG (Base address 04 HEX) to Table 3-7 on page 3-20 to determine the internal functional error.

Note

An open thermocouple will not cause failure of bit, but will cause the associated converted data register to float to negative full scale.

Program Examples

Board Initialization

A typical initialization sequence for the Thermocouple Board is shown in Figure 3-1 on page 3-21. The BIT flag is checked, and all operating parameters are loaded into the appropriate registers.

Table 3-7: Internal Functional Errors

Internal Functional Errors							
Bit D15	**Bit D14**	**Bit D13**	**Bit D12**	**Bit D11**	**Bit D10**	**Bit D09**	**Bit D08**
N/A	N/A	N/A	N/A				

Bit D07	Bit D06	Bit D05	Bit D04	Bit D03	Bit D02	Bit D01	Bit D00
N/A		N/A		N/A			

Internal Functional Errors Bit Definitions

Bit D0:	* ADC Operational Error
Bit D01:	* EEProm-Store Failed
Bit D02:	Checksum Error
Bit D03:	N/A
Bit D04:	RAM Test Error
Bit D05:	N/A
Bit D06:	Board Temp Outside VME Spec Temp
Bit D07:	N/A
Bit D08:	Internal I/O Error
Bit D09:	* Watchdog Reset Invoked
Bit D10:	Reference Voltage Error
Bit D11:	* ADC Calibration Error
Bit D12:	N/A
Bit D13:	N/A
Bit D14:	N/A
Bit D15:	N/A

* Active during scan operations. All others are inactive after RESET is completed.

Typical Single Scan Sequence

A typical measurement sequence in the SINGLE SCAN MODE is shown in Figure 3-2 on page 3-22. (Operation in the CONTINUOUS MODE is identical, except that the processing continues after initiation until stopped by the selection of another mode, or by a reset operation.)

Figure 3-1: Program Flowchart – Board Initialization

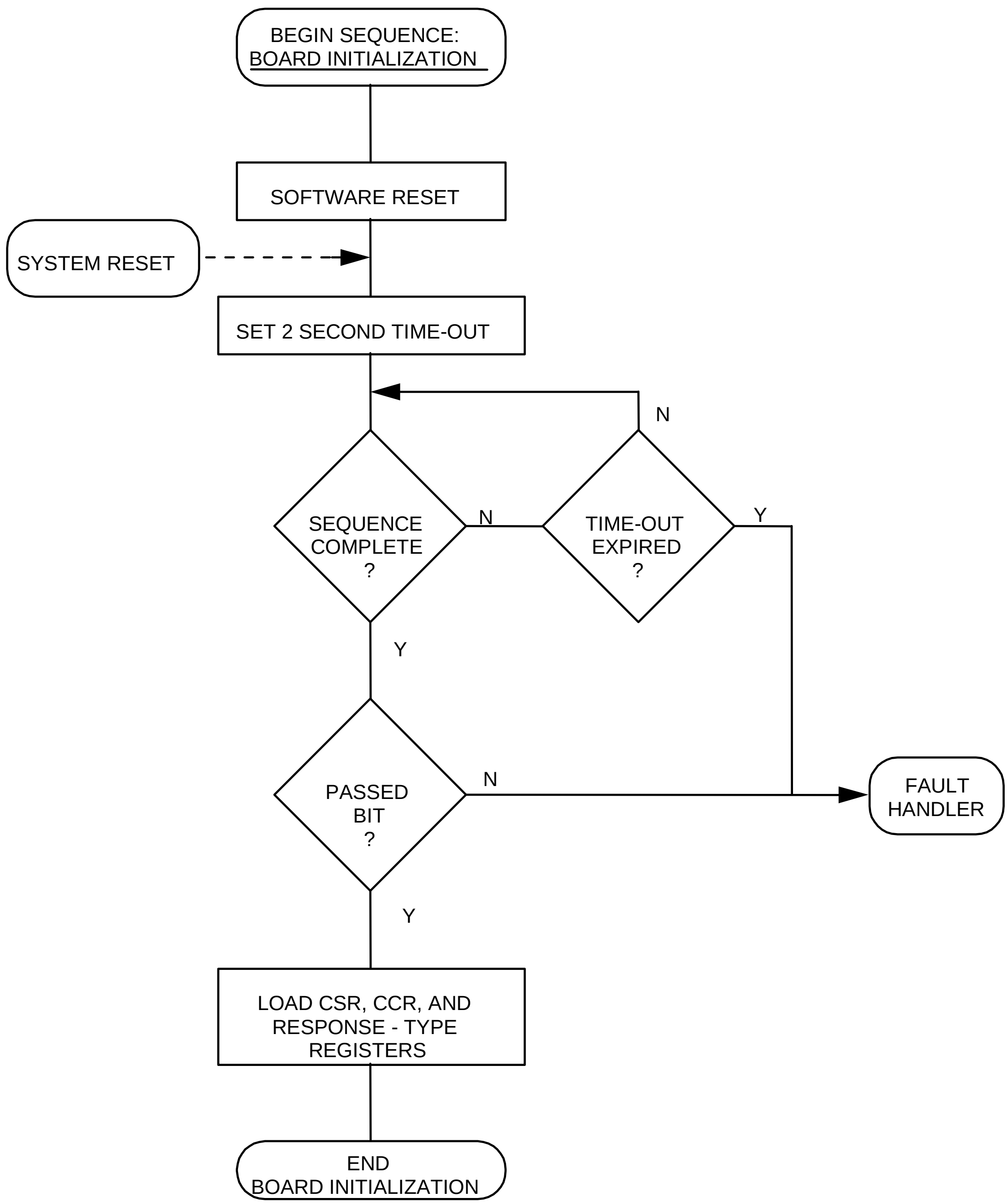
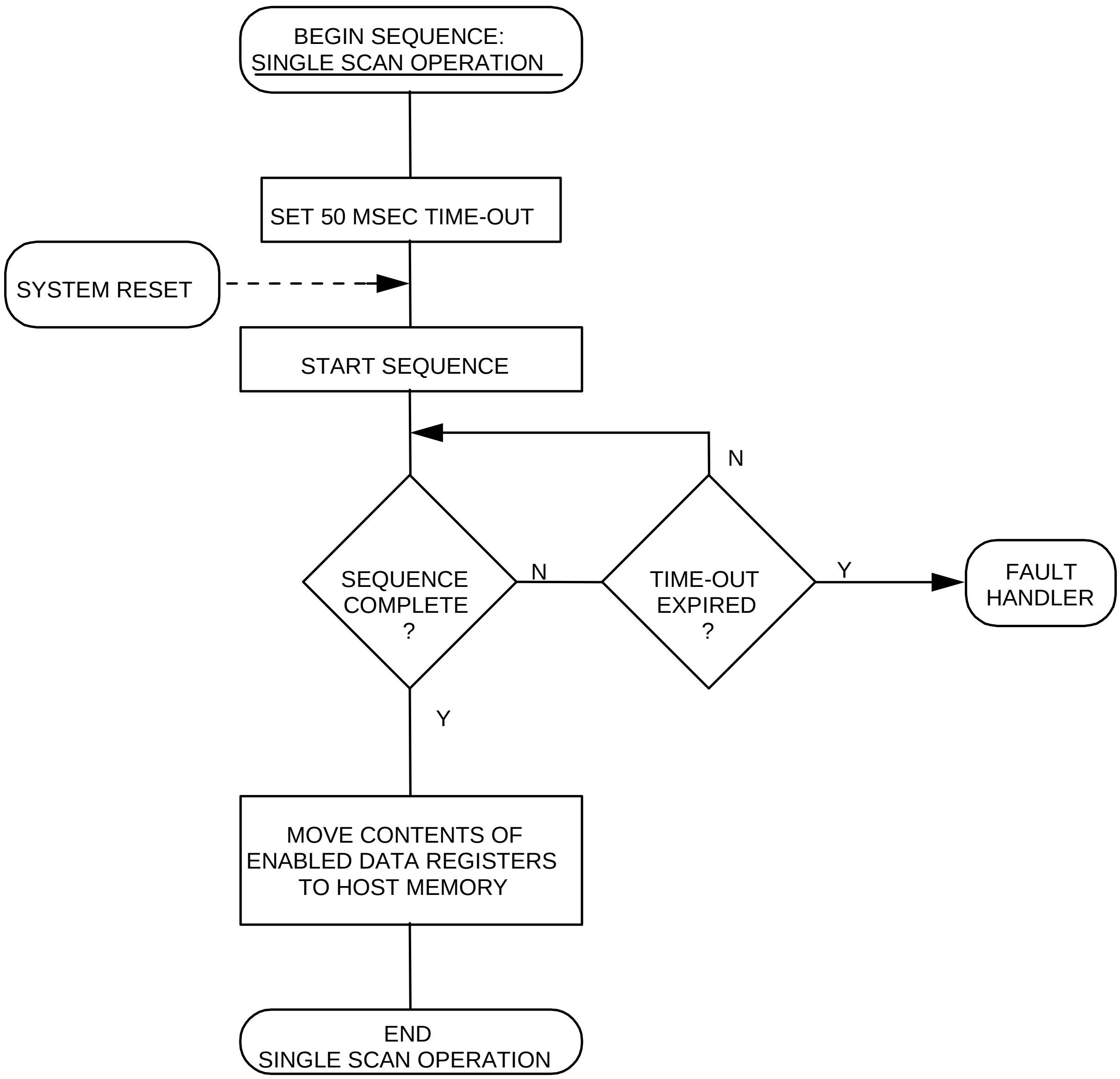


Figure 3-2: Program Flowchart – Single Scan Operation



Chapter 4

Theory of Operation

The Thermocouple Board is an 8-channel, low level, intelligent analog input board that is designed specifically to condition, digitize, and process the signals from thermocouples. After filtering, amplification, and multiplexing the input signals are digitized by a 13-bit Analog-to-Digital Converter (ADC). This data is subsequently processed by a microprocessor-based digital signal processor. The processor controls all board operations and provides final data in a variety of program selectable formats.

Sensor types can be mixed in any combination of thermocouples and other low level signal sources. Definitions of the input configurations and output data formats are program controlled. Individual channel gains are jumper selected. Calibration parameters for each channel are stored in nonvolatile memory, thereby eliminating the need for multiple mechanical adjustments. Built-in-Test (BIT) functions permit the resident processor to use a precision internal reference to maintain calibration of the ADC.

This chapter is divided into the following sections:

- VMEbus Control Interface
- Controller and Processor
- Input Signal Conditioning
- Multiplexing and Digitizing
- Signal Processing
- Built-in Power Converter

Internal Functional Organization

The Thermocouple Board is divided into the following functional categories, as illustrated in Figure 1-1 on page 1-4. All Thermocouple Board functions are discussed in detail throughout this manual.

VMEbus Control Interface

The Thermocouple Board communications registers are memory mapped as sixteen, 16-bit words. The registers are contiguous, and may be user-located on any 16-word boundary within the short I/O address space of the VMEbus. The board can be user-configured to respond to either short supervisory or non-privileged bus communications.

During each *READ* or *WRITE* operation, all VMEbus control signals are ignored unless the board-selection comparator detects a match between the on-board address selection jumpers shown in Figure 4-1 on page 4-4, and the address and address-modifier lines from the backplane. If a valid match is detected, and if the resident processor has granted the bus by asserting the PBGRANT flag, the board responds to the VMEbus request for a data transfer. When transfer conditions have been satisfied, the open-collector DTACK interface signal is asserted ON (LOW). Subsequent removal of the VMEbus *READ* or *WRITE* command causes the board-generated DTACK signal to return to the OFF (HIGH) state.

Availability of the board's internal data bus is arbitrated between the VMEbus and the resident processor, using the processor's inherent arbitration capabilities. Internal use of the bus is indicated by negation of the PBGRANT signal, which inhibits external access until the current internal operation has been completed. Most (95 percent) of VMEbus accesses will receive a response within 300 nanoseconds.

After board selection has occurred, three groups of VMEbus signals control VMEbus communications with the board:

1. Data Bus lines D00 to D15
2. Address lines A01 to A04
3. Bus Control Signals:

   (1) WRITE *
   (2) DS0*, DS1*
   (3) SYS CLK
   (4) SYS RESET* ("*" = Asserted Low)

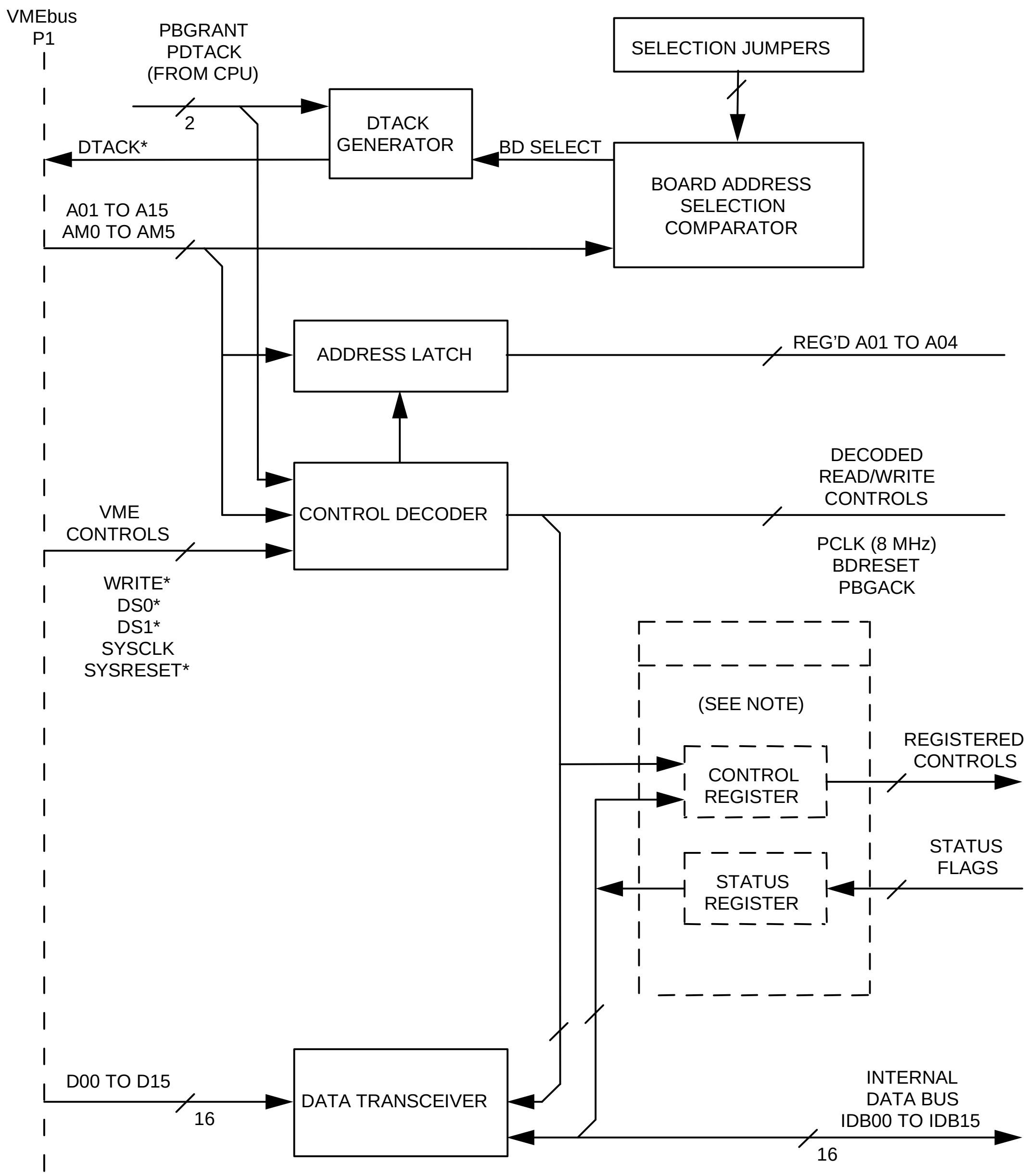
Data Bus lines are bidirectional and move data to and from the board through a 16-bit data transceiver in response to control signals from the control decoder. The data transceiver serves as a buffer for the internal data bus which interconnects all data devices on the board.

Address lines A01 through A04 provide access to the 16 communication registers used by the Thermocouple Board. The control signals determine whether data is to be moved to the board (*WRITE*) or from the board (*READ*), provide the necessary data strobes (DS0, DS1), and supply a 16 MHz clock (SYS CLK) for use by on-board timers. A SYS RESET input resets all timers and flags. The 16 communications registers reside in processor high memory, but are decoded to appear to the VMEbus as starting at a relative board address of 0000.

Static controls are latched into the CONTROL REGISTER, and are used primarily to establish the operational mode of the board. Status flags are read through the STATUS REGISTER. The control and status registers are referred to collectively as the Control Status Register (CSR). All of the CONTROL REGISTER active outputs can be monitored directly through the STATUS REGISTER. Chapter 3 describes all functions of the CSR in detail.

The Board Identification Register (BIR) is a 16-bit *read-only* register that contains the Thermocouple Board identification code.

Figure 4-1: VMEbus Control Signals and Interface Logic



Note

CSR in the figure above is mapped into CPU memory.

Controller and Processor

The Thermocouple Board is controlled by the resident processor which also performs all signal processing operations. The processor is shown in Figure 4-2 on page 4-7. An 8 MHz clock is derived from the VMEbus interface, in addition to the board reset (BDRESET) and bus grant acknowledge (PBGACK) signals. Operating firmware and linearization constants are contained in EEPROM. Program variables reside in RAM and include the calibration parameters that are relocated from nonvolatile memory during initialization.

Calibration constants, which must be modifiable by the program, reside in nonvolatile EEPROM. Nonvolatile constants are updated during calibration operations, and are moved to RAM during initialization. A CAL ENABLE/DISABLE jumper prevents inadvertent modification of EEPROM contents.

The 16 VMEbus communication registers are located in RAM, and are controlled both by the VMEbus and by the processor. All VMEbus commands, status flags, and formatted output data are routed through these registers. The processor controls board functions through a 12-bit output data latch, and reads internal flags through a 6-bit input port.

Input Signal Conditioning

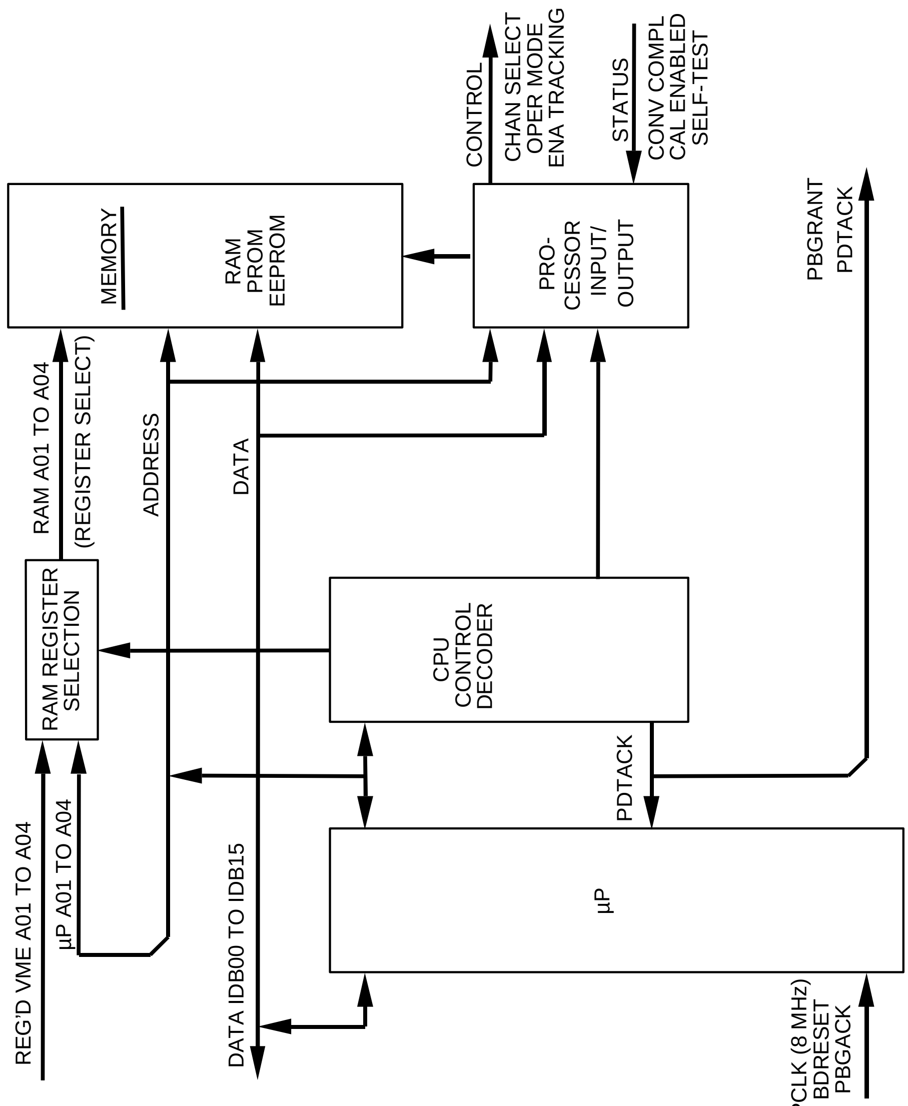
Analog inputs are received through two identical, four-channel, isolated, differential signal conditioning modules as shown in Figure 4-3 on page 4-8. The signal conditioners filter the inputs and provide full scale ranges of ±30, 60, or 90 mV. All inputs are protected for differential overvoltages to 130 Vrms, and are mutually isolated to withstand potentials as high as 1,000 Peak Volts. Open-sensor detection provides a negative over-range level for any input which has a source resistance of greater than approximately 5 Megohms.

A Cold Junction Compensation (CJC) sensor provides a +10 mV/K signal for the processor to use in establishing a reference temperature for thermocouple inputs. The sensor is thermally connected to the P3 connector, to which all thermocouple connections are made. For remote termination of thermocouples, an external sensor may be jumper-substituted for the on-board sensor.

Multiplexing and Digitizing

Each of the two 4-channel signal conditioning modules multiplexes the four associated input channels. Selection of either of the modules is performed by enabling or disabling the modules, the outputs of which are connected together. After multiplexing, the conditioned analog signal is routed through a programmable inverter before appearing at the input of a second multiplexer. In addition to the conditioned input signal, the second multiplexer monitors the cold junction sensor and the on-board precision voltage reference. A fixed gain x2 amplifier raises the signal level to a 10 V range at the ADC.

Figure 4-2: Controller and Processor



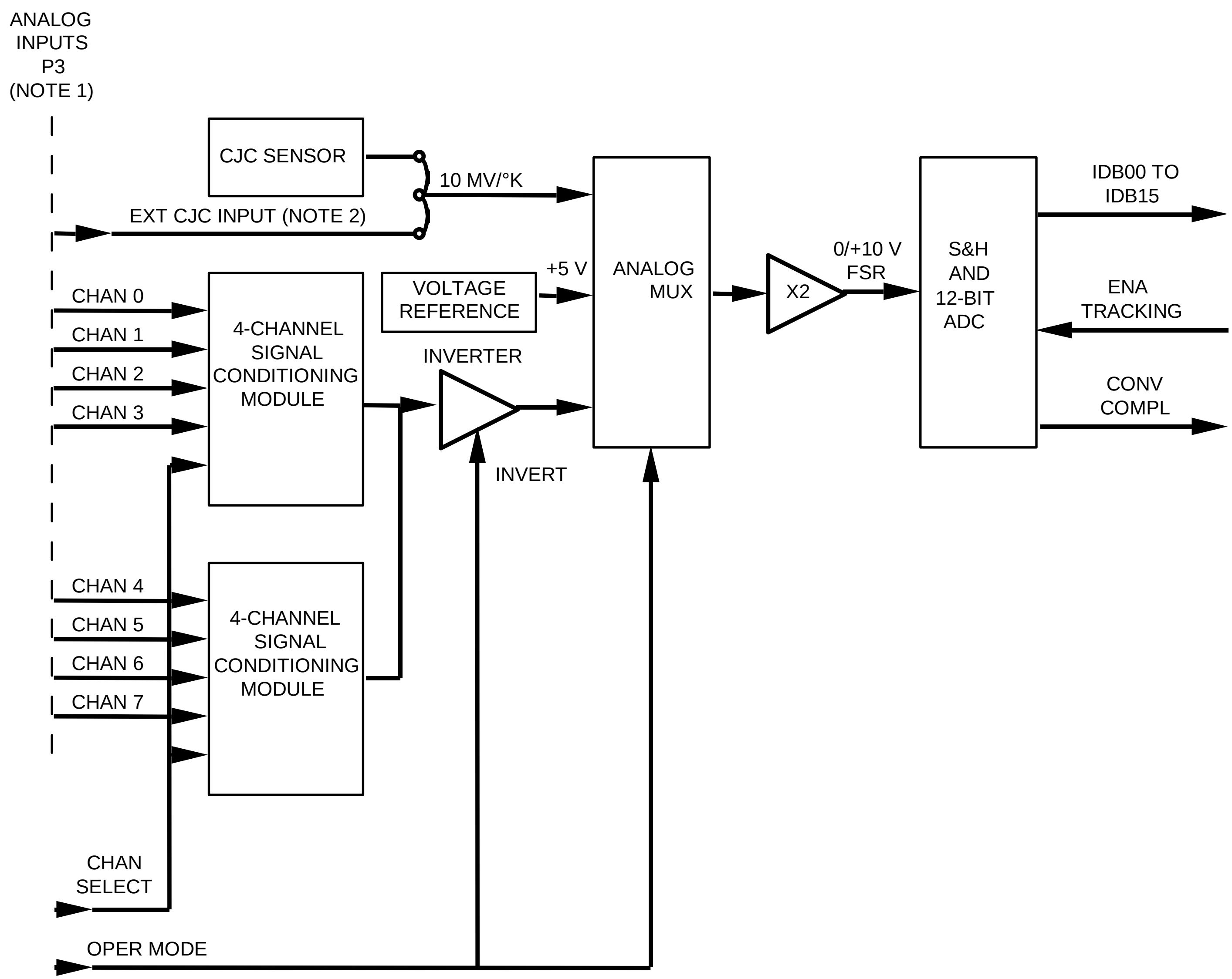


Figure 4-3: Thermocouple Board Signal Conditioning and Digitizing

Note

1. **The P3 connector consists of a screw-terminal block and a mating connector.**
2. **An external trigger input can be substituted for the external CJC input.**

The programmable inverter provides an additional digitizing bit, by inverting negative signals and thereby allowing the 12-bit ADC to operate exclusively in the region between zero and +10 V. The result is a 13-bit bipolar converter that is self-calibrating against the internal reference.

An A/D conversion is initiated by the processor after disabling TRACKING, and completion of the conversion is indicated by a CONV COMPL signal from the converter. The processor controls all operations associated with the converter.

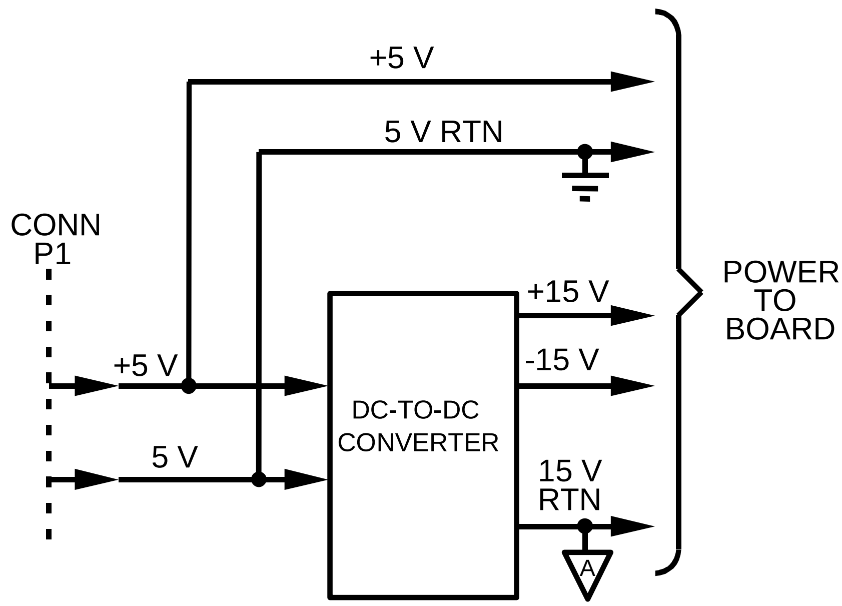
Signal Processing

After the conditioned analog inputs have been digitized, the processor performs all remaining conditioning and processing, including error correction, scaling, linearization, and output formatting. Processed data is loaded into eight of the VME registers for access through the VMEbus. Control and processing are described in detail in Chapter 4.

Built-In Power Converter

Electrical power for the Thermocouple Board analog networks is supplied by the DC-to-DC Converter shown in Figure 4-4 below. The converter transforms 5V logic power into regulated and isolated ±15 VDC power, with a load capacity of approximately 170 milliamperes on each 15 V bus.

Figure 4-4: ±15 VDC Board Power



Chapter 5 Maintenance

This chapter provides information relative to the care and maintenance of the Theromcouple Board product.

If the product malfunctions, verify the following:

- Software
- System configuration
- Electrical connections
- Jumper or configuration settings
- Boards fully inserted into their proper connector location
- Connector pins are clean and free from contamination
- No components of adjacent boards are disturbed when inserting or removing the board from the VMEbus card cage
- Quality of cables and I/O connections

User level repairs are not recommended. Contact your authorized GE Fanuc distributor for a Return Material Authorization (RMA) Number. **This RMA Number must be obtained prior to any return.**