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AIM7
Thermocouple Input Module

The AIM7 Thermocouple Input Module accepts signals from thermocouple types J, K, S, T, B, E, and R, or generic voltages up to ±100mV full scale. The AIM7 offers 16 channels of differential input, as well as guard and ground screw terminals.

The AIM7 provides channel selection through on-card multiplexing. Gain is fixed at 100 volts/volt. On-card cold junction reference circuitry provides an accurate temperature reference for thermocouple measurements.

Signals from the AIM7 are routed along the AN OUT signal path to the system global amplifier and A/D converter where programmable gain can be applied before A/D conversion.

All thermocouple inputs are applied to screw terminals located on an isothermal block to minimize errors caused by temperature differences between the input connectors and the reference junction sensor. The cold junction reference sensor itself is mounted in the isothermal block to accurately measure the temperature of the block. In addition, a driven guard connection has been provided for the connection of signal shields. Guarding can minimize the noise picked up by signal input lines.

The AIM7 may be placed in slots 2-10 of the system baseboard. However, to minimize power supply thermal and noise effects, the AIM7 should be placed in the lowest numbered available slot. To install the AIM7 in a Model 500A, 500P, or 556, remove the baseboard top cover and place the module in the desired slot with the component side facing the power supply. For the Model 570 or 575, open the system clamshell cover and place the module in the system option slot with the components facing upward.

CAUTION

Always turn off the data acquisition system power supply before installing or removing modules. Always operate the system with the top cover in place to minimize the possibility of EMI radiation.

User Configured Components

The signal input screw terminals located on the isothermal block are the only user-configured components on the AIM7 module. For the location of these terminals, refer to Figure 1. Note that the terminals provide connections for the 16 input channels as well as separate connections for ground and guard.

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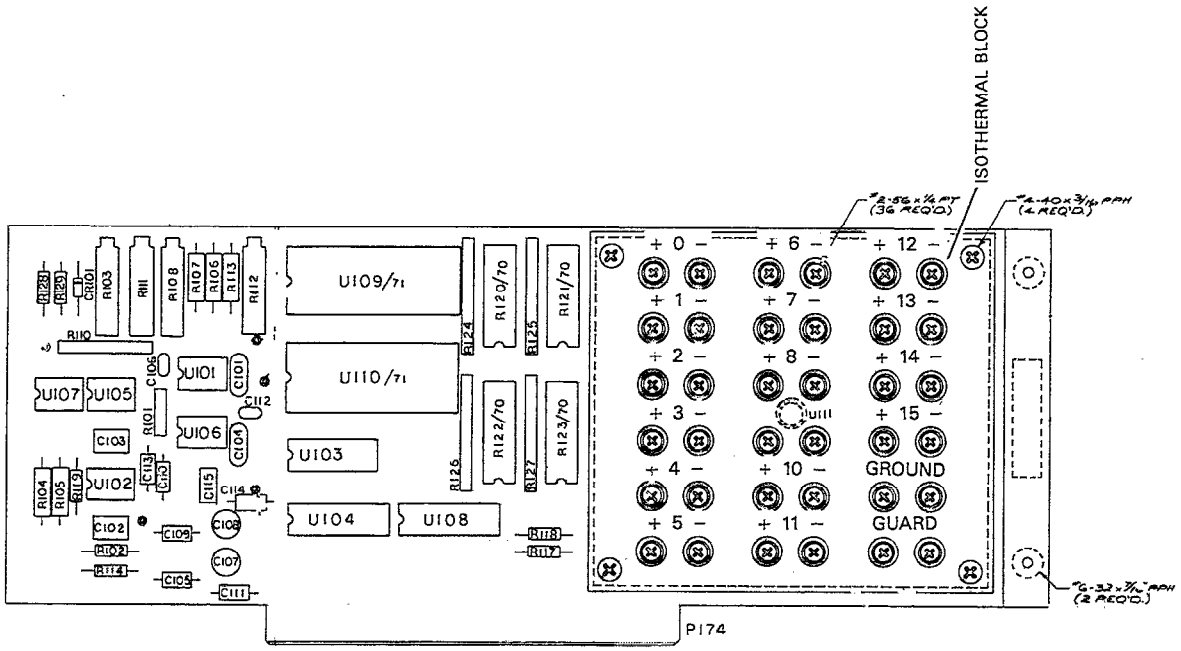


Figure 1. AIM7 Module Configuration

Connecting Terminals

The AIM7 accepts up to 16 differential input channels. These channels are marked channel 0 through channel 15. Each channel has two input terminals labeled (+) and (-) for positive and negative inputs, respectively. Note that you must observe proper polarity when connecting thermocouples to the AIM7 module. The positive thermocouple wire must be connected to the (+) terminal, and the negative thermocouple wire must be connected to the (-) terminal. The negative TC wire is usually red. Typical connections for channel 0 are shown in Figure 2. In this example, the shield is connected to the guard terminal; guarded connections are discussed in the following section.

Color coding of thermocouple wires varies according to type. Table 1 gives the ANSI color codes for the various thermocouple types supported by the Module. When adding extension cable, use only the specific type of cable recommended for the thermocouple being used.

Table 1. Thermocouple Color Codes

Type	Material	(+) Wire	(-) Wire
B	Platinum 30% rhodium Platinum 6% rhodium	Gray	Red
E	Chromel-constantan	Purple	Red
J	Iron-constantan	White	Red
K	Chromel-alumel	Yellow	Red
R	Platinum 13% rhodium Pure platinum	Black	Red
S	Platinum 10% rhodium Pure platinum	Black	Red
T	Copper-constantan	Blue	Red

CAUTION

Maximum input voltage is ±15V (power on), or ±10V (power off). Exceeding these values may damage the module. If any input exceeds ±10V (power on), measurement error is likely to occur.

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Guarding

On long signal runs, or in electrically noisy environments, use shielded cable to reduce noise pickup. If your temperature reading is unstable, noise induced into the thermocouple wire may be the problem.

When using shielded thermocouples with the AIM7, the shield should be connected to one of the AIM7 guard terminals rather than module ground or baseboard ground. These terminals are actively driven by an on-card buffer amplifier, so that GUARD is maintained at the common mode voltage of the input signal.

If the shield is connected in this manner, it should not be connected to the thermocouple signal wires or to ground at any point. Doing so will short-circuit the output of the guard amplifier, possibly damaging the AIM7.

For guarding to be effective, the same shield must carry both the positive and negative leads of the thermocouple signal, and no other signal lines. Each input line should have its own shield, and all shields should be connected to one of the GUARD terminals. Figure 2 shows typical guarded connections. Note that the shield is connected to GUARD, while the thermocouple signal lines are connected to the (+) and (-) terminals of channel 0.

Connecting Thermocouples

A thermocouple is a sensor made by joining two dissimilar metals for the purpose of temperature measurement. When dissimilar metals are joined in a closed circuit, and the two junctions are held at different temperatures, a small electric current will flow through the circuit. The voltage generated under such conditions will depend on the temperature difference between the two junctions as well as the types of metals being used.

When thermocouples are used for temperature measurement, one junction is kept at a known reference temperature (often the melting point of ice: 0°C). Tables and curves that describe the relationship of thermocouple voltage to temperatures assume that the temperature of the reference junction is 0°C.

If the temperature of the reference junction is known precisely, however, it is not necessary that it be maintained at 0°C. The same tables and curves will be accurate if compensation is made for the temperature of the reference junction. Such compensation is often referred to as "cold junction compensation", and is achieved by adding to the voltage of the thermocouple the voltage which would be produced by measuring the temperature of the reference junction.

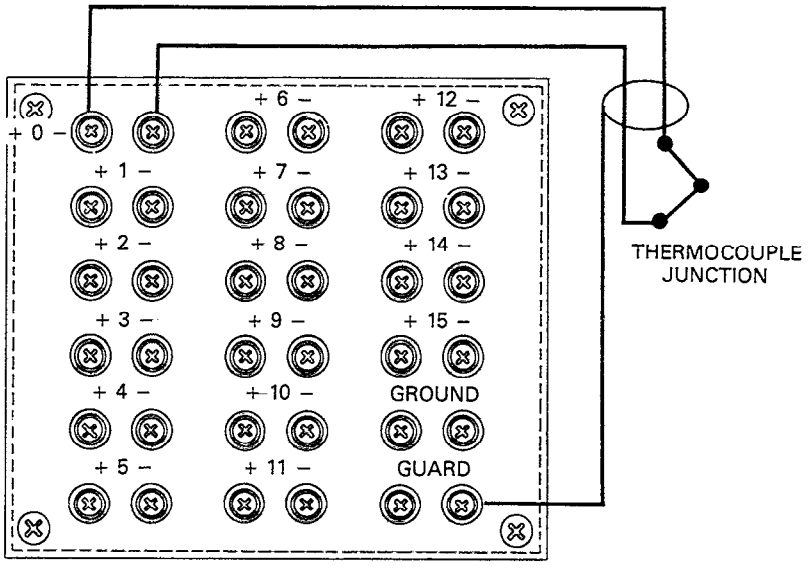


Figure 2. Typical AIM7 Connections (Channel 0, Guarded Connections shown)

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For example, if the reference junction is at 25°C, and the measuring junction is at 75°C, then the thermocouple will measure a difference of 50°C rather than the expected 76°C. Therefore, the output of the thermocouple will be smaller than expected. Adding the voltage equivalent of a 25°C difference will compensate for the fact that the reference junction is not actually at 0°C.

Cold junction reference circuitry located on the AIM7 measures the temperature of the reference junction at the screw terminals. Because of the isothermal block, thermal offsets between the measurement point and the terminals are kept to a minimum. When the SELECT CHANNEL command is performed with a value of 32, the voltage output of the compensation circuitry can be read by the A/D converter. Channel 32 (cold junction reference) will read 100mV/°C. At 0°C this channel will read 0V, and at 50°C, 5V.

Because the temperature/voltage relationship of the reference sensor is linear, the voltage produced by the compensation circuitry easily converts to temperature in software. To find the appropriate conversion voltage, consult the tables for the particular type of thermocouple being used. Find the voltage produced by that type of thermocouple at the temperature of the reference junction, and then add the correction voltage to the reading from the thermocouple itself.

In the previous example, consult the table to determine the compensation voltage at 25°C. If the thermocouple were type T (Copper/Constantan), the voltage at 25°C would be 0.992mV. Add this voltage (in software) to the actual voltage output of the thermocouple.

Unfortunately, the voltage output of thermocouples is non-linear with respect to temperature. When using the AIM7 module, linearization and the conversion of the voltage into temperature must be carried out in software. This can be done by using a polynomial equation describing the specific voltage/temperature relationship for the thermocouple in question, by looking up the correct value in a table, or by using piecewise linear approximations.

Keithley's various software packages perform voltage-to-temperature conversion and linearization automatically.

The AIM7 is factory configured to provide a gain of 100 volts/volts on each of the 16 input channels. This gain value is suitable for using thermocouple types B, E, J, K, R, S, and T.

When an appropriate gain is applied via the PGA on the A/D module, the A/D converter can achieve an average resolution of 1°C or better across the useful range of the thermocouple. Table 2 indicates the average temperature increments represented by each digital step for a 12-bit and 16-bit modules. In either case, these figures will give a good indication of the resolution to expect when measuring the full temperature range of the AIM7.

Resolution can be increased with any of the following modifications:

1. using a thermocouple with a smaller temperature range, and increasing the PGA gain,
2. setting the A/D converter to a smaller input range (for example, 0 to 10V when temperatures below 0°C will not be measured), or
3. by using a 16-bit A/D module instead of a 12-bit A/D module. This will increase resolution by a factor of 16.

Table 3 gives temperature ranges and output voltages for the thermocouple types supported by the AIM7 module. For all those listed, better than 1°C resolution can be expected as long as a suitable PGA gain is used (see Table 2).

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Table 2. Average Temperature Value of Conversion Step with A/D Converter (Resolution)

TC* Type	A/D Range	PGA Gain	AIM7 Gain	AIM7 F.S. Input	12-bit A/D Resolution Volts	12-bit A/D Resolution Temp.	16-bit A/D Resolution Volts	16-bit A/D Resolution Temp.
B (850C)	0-10V	x5	x100	0-20mV	4.88µV	0.61C deg	0.305µV	0.038C deg
E (500C)	0-10V ±10V	x1 x1	x100 x100	0-100mV ±100mV	24.4µV 48.8µV	0.30C deg 0.60C deg	1.526µV 3.052µV	0.019C deg 0.038C deg
J (350C)	0-10V	x2	x100	0-50mV	12.2µV	0.22C deg	0.763µV	0.014C deg
K (600C)	0-10V ±10V	x2 x2	x100 x100	0-50mV ±50mV	12.2µV 24.4µV	0.29C deg 0.58C deg	0.763µV 1.526µV	0.018C deg 0.036C deg
R (850C)	0-10V	x5	x100	0-20mV	4.88µV	0.38C deg	0.305µV	0.023C deg
S (850C)	0-10V	x5	x100	0-20mV	4.88µV	0.40C deg	0.305µV	0.025C deg
T (200C)	0-10V ±10V	x5 x5	x100 x100	0-20mV ±20-mV	4.88µV 9.76µV	0.09C deg 0.18C deg	0.305µV 0.610µV	0.006C deg 0.012C deg

NOTES:

1. *Temperature shown is a value mid-way between the minimum and maximum useable range for the thermocouple.
2. Calculations made at indicated temperature. Resolution may vary at higher and lower temperatures.
3. Where calculations are made only for 0-10V A/D range, thermocouple does not support readings below zero C.
4. Resolution is maximum theoretical resolution. Accuracy and resolution will be affected by noise and the accuracy of conversion algorithms.

Table 3. Useful Temperature Ranges and Associated Voltages

Type	Material	Range (°C)	Range (emf)
B	Platinum 30% Rhodium Platinum 6% Rhodium	0 to 1700	0.00mV to 12.426mV
E	Chromel-constantan	-200 to 900	-8.824 to 68.783mV
J	Iron-constantan	0 to 750	0.00mV to 42.283mV
K	Chromel-alumel	-200 to 1232	-5.973 to 49.988mV
R	Platinum 13% Rhodium Pure Platinum	0 to 1450	0.00mV to 16.741mV
S	Platinum 10% Rhodium Pure Platinum	0 to 1450	0.00mV to 14.973mV
T	Copper-constantan	-200 to 350	-5.602 to 17.816mV

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Commands

AIM7 module commands are listed in Table 4. Table 5 summarizes the locations for the slot-dependent commands.

Table 4. Commands Used with the AIM7 Module

Command	Location
SELECT CHANNEL	CMDA (slot-dependent)

Table 5. Locations for Slot-Dependent Commands

Slot	SELECT CHANNEL (CMDA)
Slot 2	xxx82
Slot 3	xxx84
Slot 4	xxx86
Slot 5	xxx88
Slot 6	xxx8A
Slot 7	xxx8C
Slot 8	xxx8E
Slot 9	xxx90
Slot 10	xxx92

Where xxx=1st three digits of the IBIN interface address; e.g. "CFF".

SELECT CHANNEL

The SELECT CHANNEL command is used to select which of 16 channels on the AIM7 module is directed to the A/D programmable gain amplifier and A/D converter.

In all cases, the number of the channel being measured is the value to write to the SELECT CHANNEL location, as shown in Table 6. If channel 0 is to be selected, a value of 0 would be written to the SELECT CHANNEL location; if channel 5 is to be selected, a value of 5 would be written to SELECT channel and so on.

On the AIM7 module, writing a value of 32 to the SELECT CHANNEL location selects the voltage output of the cold junction compensation circuitry located on the module. The use of this reading is described in the section on connecting thermocouples.

SELECT CHANNEL should normally be followed by the SELECT SLOT command, which is loaded into software with the slot number in which the AIM7 module is installed (see the manual for your master analog measurement module). If successive readings are taken from various channels located on the same module, the SELECT SLOT command need not be issued for each reading. Similarly, for successive readings from a single channel, SELECT CHANNEL need only be issued once.

SELECT CHANNEL and SELECT SLOT must be issued at least once before starting an A/D conversion.

Table 6. Values Written to SELECT CHANNEL Location

Function	Binary	Hex	Decimal
Channel 0	00000	H0	0
Channel 1	00001	H1	1
Channel 2	00010	H2	2
Channel 3	00011	H3	3
Channel 4	00100	H4	4
Channel 5	00101	H5	5
Channel 6	00110	H6	6
Channel 7	00111	H7	7
Channel 8	01000	H8	8
Channel 9	01001	H9	9
Channel 10	01010	HA	10
Channel 11	01011	HB	
Channel 12	01100	HC	12
Channel 13	01101	HD	13
Channel 14	01110	HE	14
Channel 15	01111	HF	15
Cold Junction Reference Output	100000	H20	32

Calibration

This section contains information necessary to calibrate the AIM7 module. Accurate calibration depends both upon the accuracy of the calibrating equipment as well as the skill of the technician. If you are unsure how to calibrate the AIM7 module, please do not attempt the following procedures. Contact our Product Support Department to make arrangements for factory calibration of your AIM7.

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Environment Conditions

Calibration of the AIM7 module should be performed at an ambient temperature of 23°C ±5°C. Turn on the system power with the AIM7 module installed and allow it to warm up for at least 10 minutes before beginning the calibration procedure.

Recommended Calibration Equipment

Use the equipment below to calibrate the AIM7 module. Other equipment may be substituted as long as relevant specifications are at least as good as these given below:

1. Digital Voltmeter (±0.015% basic DC accuracy)
2. DC Millivolt Reference Source (±0.05% accuracy).
3. Digital Thermometer (±0.3°C accuracy).

Calibration Procedures

Use the following procedures to calibrate offset and gain, the cold junction reference circuitry, and to adjust for maximum CMRR (common mode rejection ratio). Adjustment locations, test points, and input connections are shown in Figure 3.

Offset and Gain Adjustments

Improper gain and offset adjustments will affect overall measurement accuracy of the module. Use the following procedure to calibrate these functions.

1. Install the AIM7 module in slot 4 of the system baseboard.
2. Connect the DC calibrator high (+) terminal to the (+) terminal of channel 0, and connect the calibrator low (-) terminal to the (-) terminal of channel 0. Use shielded cable and connect the shield to module guard only (do not connect the shield to calibrator or module ground). Not that the calibrator outputs must be left floating and not be connected to ground at any point.
3. DEF SEG to the interface card address segment (DEF SEG = &HCFFD) and POKE the SELECT CHANNEL location with a value of 0 in order to select channel 0 (CFF86).

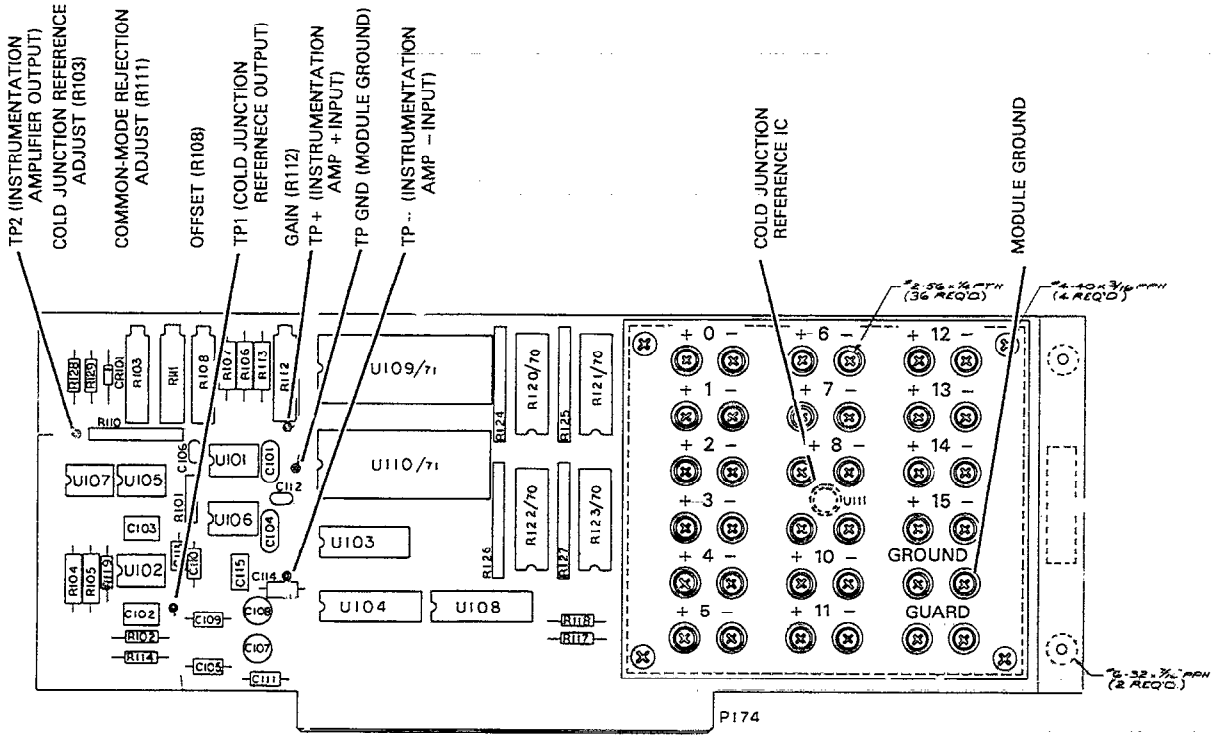


Figure 3. Calibration Adjustments and Test Points

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4. Connect the DMM high input lead to TP2 of the AIM7. Connect the DMM low terminal to TP GND. Select the DCV function and place the DMM in the autorange mode.
5. Set the DC calibrator output voltage to exactly 0V.
6. Adjust the offset control (R108) for a reading of 0V ±1mV on the DMM.
7. Move the DMM high input lead to TP2 of the AIM7.
8. Set the calibrator voltage to exactly 100.00mV.
9. Set the gain adjustment (R112) for a reading of 10.000V ±1mV on the DMM.
10. Repeat steps 4 through 9 until no further change is seen in the off-set readings.

Cold Junction Reference Adjustment

The cold junction reference adjustment supplies a voltage of 100mV/°C that is used by the software to calculate the final reading. As with the offset and gain adjustments, incorrect calibration of the cold junction reference circuitry will affect measurement accuracy. Use the following procedure to calibrate the cold junction reference. The procedure assumes that the module is still installed in slot 4 of the system baseboard.

1. Connect the DMM high input lead to TP1 of the AIM7 module. Connect the DMM low lead to module ground. Set the DMM to measure DCV in the autoranging mode.
2. Apply thermal grease to the tip of the measurement probe.
3. Remove the four screws that secure the isothermal block insulator and remove the insulator (the block itself is secured by screws on the back side of the circuit board and should not be removed).
4. Locate the cold junction reference sensor IC (U111) at the center of the isothermal block. Touch the temperature probe tip to the case of this IC and allow five minutes for the reading to stabilize.
5. Adjust the cold junction reference control (R103) for a reading of 100mV x T°C on the DMM. For example, at 23°C, adjust for a reading of 2.3V.
6. Replace the isothermal block insulator and secure it with the four screws removed earlier.

Common-Model Rejection Adjustment

The common-mode rejection adjustment should not normally be required in the field; however, the following procedures may be used if the common-mode rejection adjustment potentiometer has been adjusted inadvertently, or in cases where it is suspected that the CMRR of the module is below par. Symptoms of lower than normal CMRR may show up as noisier than usual temperature readings, depending in the type of noise, and the way the noise is being introduced into the thermocouple signal.

Note that the offset and gain controls will require re-adjustment if the CMRR adjustment is made.

Proceed as follows (assumes the use of BASIC):

1. Connect the DMM high input lead to TP2 of the AIM7. Connect DMM low to module ground. Place the DMM in DCV and select autoranging.
2. Connect a jumper wire between the (+) and (-) terminals of channel 0. Connect the high lead of the DC calibrator to these two terminals, and connect the low signal lead of the calibrator to module ground.
3. Issue a DEF SEG command to change to the segment address of the IBIN interface. For example, if the IBIN is addressed at CFF80, issue the command "DEF SEG = &HCFF)". POKE the SELECT CHANNEL location with a value of 0 in order to select channel 0 (Address xxx86).
4. Set the DC calibrator output for a value of exactly 10.000V.
5. Adjust the common-mode rejection control (R111) for a reading as close to 0V as possible, as seen on the DMM.
6. Set the calibrator output to a value of exactly -10.000V.
7. Adjust R111 again for a reading as close as possible to 0V.
8. Repeat steps 4-7 until a minimum change is seen in the output when going from +10V to -10V inputs.
9. Disconnect the DC calibrator and remove the jumper wire connected between the (+) and (-) terminals of channel 0.

Theory of Operation

A schematic diagram of the AIM7 module may be found on drawing number 500-426, located at the end of this supplement.

Thermocouple input signals are applied to screw terminals located on the isothermal block. This block is used to minimize thermal offsets that would otherwise decrease temperature accuracy. The (-) terminals of the input channels are connected to ground through 1MΩ resistors, R120-123. These resistors are used to prevent the output of the instrumentation amplifier from saturation due to the effects

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of stray capacitance and offset current at the input.

From the input terminals, signals are applied to two analog multiplexers, U109 and U110. The multiplexers are driven by U104, a quad transparent latch (74LS75), which stores the status of the F0-F3 data lines. The enable lines are driven by U108, also a quad transparent latch (74LS75), which stores data from F5. Data lines F0-F3 and F5, and thus these two latches, are controlled by writing the appropriate value (0-15, or 32) to the SELECT CHANNEL location (signal line CMDA).

The outputs of the multiplexers, U109 and U110, are routed to the inputs of the instrumentation amplifier, which is made up of ICs U101, U106, and U107. Gain for the instrumentation amplifier is set to x100 volts/volt by resistors R106, R107, and R113, along with potentiometer R112, which provides the gain trim for the module. R108 provides the offset trim adjustment, while R111 gives a means to maximize common-mode rejection. The output of the instrumentation amplifier is filtered by R119 and C115, which make up a single-pole low-pass filter.

After filtering, the output of the instrumentation amplifier is directed to one input of U103, a one-of-two analog switch (ADG200). The second input of U103 is connected to the output of the cold junction reference circuitry made up of U102 and U111. The output of U103 drives the AN OUT pathway exiting the module. U103 is controlled by the output of one latch in U108, which stores the status of data line F5.

The 10V reference bus from the baseboard, buffered by voltage follower U102A, drives amplifier U102B configured with U111. U111 is a precision semiconductor temperature sensor with an output set to 1µA per degree centigrade. U111 is physically mounted at the center of the isothermal block to minimize thermal offsets. The current output of U111 is converted into a 100mV/°C voltage by U102B, such that at 0°C the output is 0V, and at 50°C the output is 5V. Calibration of the cold junction reference circuitry is performed by adjusting R103.

The GUARD terminals of the AIM7 are actively driven at the common-mode voltage of the selected thermocouple signal by U105, an operational amplifier configured as a voltage follower. This op amp has the low output impedance necessary to drive the guard output of the module.

Table 7. AIM7 Troubleshooting

Step	Item/Component	Required Condition	Remarks
1	Chassis to baseboard chassis.	Connect DMM high unless otherwise noted.	Leave connected
2	Connect DMM high U109, pin 1.	+15V, ±0.1V	+15V supply
3	Connect DMM high U109, pin 27.	-15V, ±0.1V	-15V supply
4	Connect DMM high to U102A, U102A, pin 3.	+10V, ±0.05V	10V referenced
5	DMM high	Connect to TP2	
6	Voltage source	Connect to + and - terminals of channel 0	Apply test signal
7	Computer	Select channel 0 on card	Use POKE statements
8	Voltage Source	Set to 0V	
9	DMM	0V ±1mV	
10	Voltage source	Set to 100mV	
11	DMM	10V ±1mV	100mV in 10V out
12		Repeat steps 6-11 for channels 1-15	Check all multiplexer inputs
13	DMM high	Connect to TP1	Cold junction reference
14	DMM	100mV x T°C	Measure U110 temperature with thermometer

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Troubleshooting Information

Troubleshoot the AIM7 module using the procedure listed in Table 7. Parts may be obtained from Keithley Data Acquisition and Control or the module may be returned to Keithley Data Acquisition and Control for repair. See the replaceable parts section of this manual for details. Note that part numbers are listed on the component layout drawing.

AIM7 Specifications

Input channels: 16 differential inputs
Input characteristics:[1]
- Range: ±100mV, x100 gain
- Protection:
  - ±15V max (powered)
  - ±10V max (unpowered)
- Accuracy: ±(0.01% + 10µV)
- Non-linearity: 0.005% of F.S.
- Common mode rejection ratio >90dB, DC to 60Hz
- Bandwidth: 1kHz
- Settling time: 2msec to 0.01%
- Offset TC: 2µV/°C max
- Voltage noise:
  - 1µV p-p max, 0.1 to 10Hz
  - 2µV p-p max, 10Hz to 1kHz

Temperature Measurement Characteristics:
- Reference Junction Sensor:
  - Output: +100mV/°C
  - Accuracy: ±0.25°C

Offset from sensor to any terminal: ±0.25°C max
Offset between any adjacent terminals: ±0.1°C max
System Resolution: [2]
- PGA = 2, ADM1 on 0 to 10V range: 12µV/count, 0.3°C/count
- PGA = 2, ADM2 on 0 to 10V range: 3µV/count, 0.075°C/count
- PGA = 10, AMD2 on - to +5V range: 0.6µV/count, 0.015°C/count

[1] All amplifier specifications with respect to input.
[2] Typical resolution, using J, K, or T thermocouple, 0 to +400°C span (assume 40µV/°C).

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ZONE	LTR	ECO NO	REVISION	ENG	DATE
	A	12270	RELEASED		6-6-84
	B	10134	ITEM 17 WAS C237-1		8-24-84
	C	10184	ITEMS WAS C350-.22		7-31-84
	D	10220	CHG SHOWN ON PRINT PER ECO		9-24-84
	E	10297	ADDED C64-330p C116, C117 PER ECO 12522 PRINT REVISED		10-17-84
	F	11708	ADDED C64-330p C116, C117 PER ECO 12522 PRINT REVISED		3-15-88
	G	12550	ADDED C64-330p C116, C117 + RATE-140K R100		5-9-88
	H	12981	CHG'D REV FROM E TO F		

| | | |

500-426 REV

ECO	REVISION	ENG	DATE
E 10297	ADDED R128, R129, C116, C117, & CR101	LB	11-3-83
F 12550	ADDED C116, C117, R130	LB	3-14-85
A 10090	RELEASED	LB	8-8-84
B 10184	C115 WAS .1	LB	8-24-84
C 10184	C115 WAS .22	LB	9-5-84
D 10280	CHG'D CONFIGURATION OF C115 TO 0.1 MFD, 50V, CERAMIC TO MEET UL REQMTS		9-26-84

NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS OTHERWISE MARKED (K-KILOHMS, M-MEGOHMS).
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE MARKED (pF-PICOFARADS).
3. ALL PUSHBUTTON SWITCHES ARE SHOWN IN THE PUSHBUTTON OUT POSITION.
4. ▽ DENOTES ANALOG COMMON.
5. ▽ DENOTES DIGITAL COMMON.
6. ▽ DENOTES SIGNAL COMMON.
7. —○— DENOTES TEST POINT.
8. CW— DENOTES CLOCKWISE ROTATION.
9. ✱ DENOTES FACTORY SELECTED VALUE.
10. ⊘ DENOTES INTERNAL ADJUSTMENT.

HIGHEST SCHEMATIC DESIGNATIONS USED			
C117	P174	R130	U111
CR101			

SCHEMATIC DESIGNATIONS NOT USED			
P101 THRU P173	R109	R115	
R116			

500			1
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