TC387
Isolated TC Amplifier

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1. DESCRIPTION

1.1 INTRODUCTION

This instruction manual contains installation and operating instructions for the Model TC387 thermocouple signal conditioner. The TC387 is a plug-in module used in several MC170-family multi-channel instrumentation cases manufactured by Validyne Engineering Corporation, Northridge, California.

1.2 GENERAL DESCRIPTION

The TC387 is a linear high gain dc amplifier with galvanic isolation from input to output. It provides reference junction ambient temperature compensation for a wide range of popular thermocouple types. The reference junction temperature sensor can be remotely connected to an isothermal terminal block, which enables a transition from thermocouple wiring to copper wiring for economy.

Input and output connections are through the card edge connector and module case wiring paths for the standard unit. An option is available for input connection through a grommet in the front panel of the TC387 to a terminal block on the printed circuit board. This option disconnects the module case input wiring and permits a higher common mode voltage rating.

Output voltage zero suppression is front panel switch selectable. A jumper can enable a thermocouple open circuit detector mode. The module provides a zero to ±10 volt input from a dc input signal ranging from ±9mV to ±100 mV full scale. The output signal is available at the front panel test point.

1.3 TECHNICAL CHARACTERISTICS

The technical characteristics of the TC387 are listed below.

Table 1-1: Technical Characteristics

INPUT SIGNAL RANGE:	±9mV FS to ±100mV FS for ±10V FS output
GAIN RANGE SELECTION:	3-Position jumper (input range) High (9mV to 25mV) 1000X, Med (18mV to 50mV) 500 X, Low (36mV to 100mV) 250X.
GAIN ADJUST POTENTIOMETER:	Continuous adjustment from 35% to 110%, 20 turn pot.

Table 1-1 (continued)

SUPPRESSION:		0 to ±10V output suppression, 20 turn pot. In/Out switch on front panel.
ISOLATION:	(TC387R)	Greater than 100Meg Ohms at ±100Vdc between input and output.
	(TC387F)	Same, at ±200Vdc.
COMMON MODE REJECTION RATIO:		135db at dc to 60Hz, 100 Ohms balanced source, Differential gain of 1000.
THERMOCOUPLE COLD JUNCTION COMPENSATION:		Jumper selectable for types E, J, R, S, B, K and T; reference junction compensation error typically less than 1° F for 20° F ambient change.
THERMAL EFFECTS (DC AMPLIFIER)		Span 0.005%/°F typical Zero 0.5ÑV/°F referred to input.
INPUT CHARACTERISTICS - SAFE DIFFERENTIAL VOLTAGE:		±20V
DIFFERENTIAL INPUT IMPEDANCE:		2Meg Ohms, paralleled by 1.0 micro-Farads. (Limited by silicon diodes and 2.2kOhm resistor above ±0.6V.)
OPEN THERMOCOUPLE DETECTOR:		Jumper-selected 80nA bias current available to detect open thermocouple
OUTPUT CHARACTERISTICS- OUTPUT VOLTAGE:		0 to ±10Vdc, 0 to 2mA, short circuit proof, not affected by line capacitance.
OUTPUT RESISTANCE:		10 Ohms maximum.
OUTPUT NOISE:		10mV rms at maximum gain.
LINEARITY:		0.05% FS, linear amplifier.
LOW PASS FILTER:		0 - 7Hz (-3db).
OPERATING MODE:		Jumper Selection -

E6 = TC-R,S; TC-R,S; or dc amplifier
E5 = TC compensation, types E,J, KTRS
E4 = TC compensation, sensor Master/Slave
E3 = TC compensation, excitation Master/Slave
E2 = Gain Range Low, Med and High
E1 = TC Open Detector, On/Off.

Table 1-1 (continued)

POWER CONSUMPTION:	+15V @ 12mA, -15V @6mA.
FRONT PANEL CONTROLS	
GAIN CONTROL (R15)	A screwdriver operated potentiometer for vernier gain adjustment.
SUPPRESSION (SUPPR): (R37,SW1)	A screwdriver-operated potentiometer for output zero suppression or elevation, plus a front panel toggle switch for in/out suppression mode selection.
OUTPUT TEST POINT:	A pin-jack for monitoring the dc signal output during setup and calibration. Pin diameter of plug is 0.08".
INTERNAL CONTROLS/JUMPERS	
INPUT ZERO, R27:	A screwdriver operated single turn potentionmeter for nulling the input amplifier offset voltage.
OUTPUT ZERO, R18:	A screwdriver operated single turn potentiometer for nulling the output amplifier offset voltage.
T.C. ZERO, R28:	A screwdriver operated single turn potentiometer for offset correction of the TC reference amplifier.
JUMPER E1:	Open circuit thermocouple Detector. ON = Detector ON OFF = Detector OFF
JUMPER E2:	Gain Range Jumper. LO = 250 MED = 500 HI = 1000 } overall gain
JUMPER E3:	Excitation Master/Slave. M = Master; S = Slave
JUMPER E4:	Sensor Master/Slave. M = Master; S = Slave.
JUMPER E5:	Thermocouple Type Selection. K,T,R,S = Type of TC J = Type of TC E = Type of TC

Table 1-1 (continued)

JUMPER E6:	Thermocouple Type/Mode. TC - $\underline{R}$,$\underline{S}$ = R or S type TC. TC - $\overline{R}$,$\overline{S}$ = not R or S type TC. B,DC = B type TC or no TC (=DC)

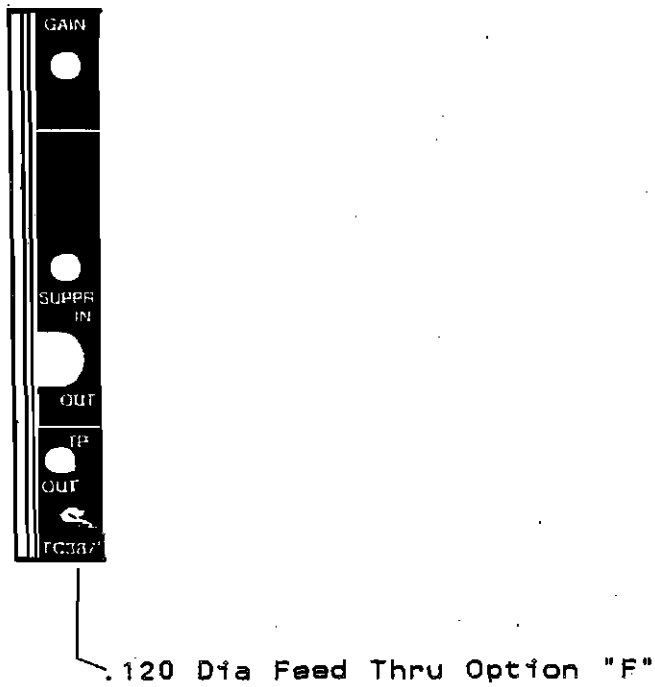
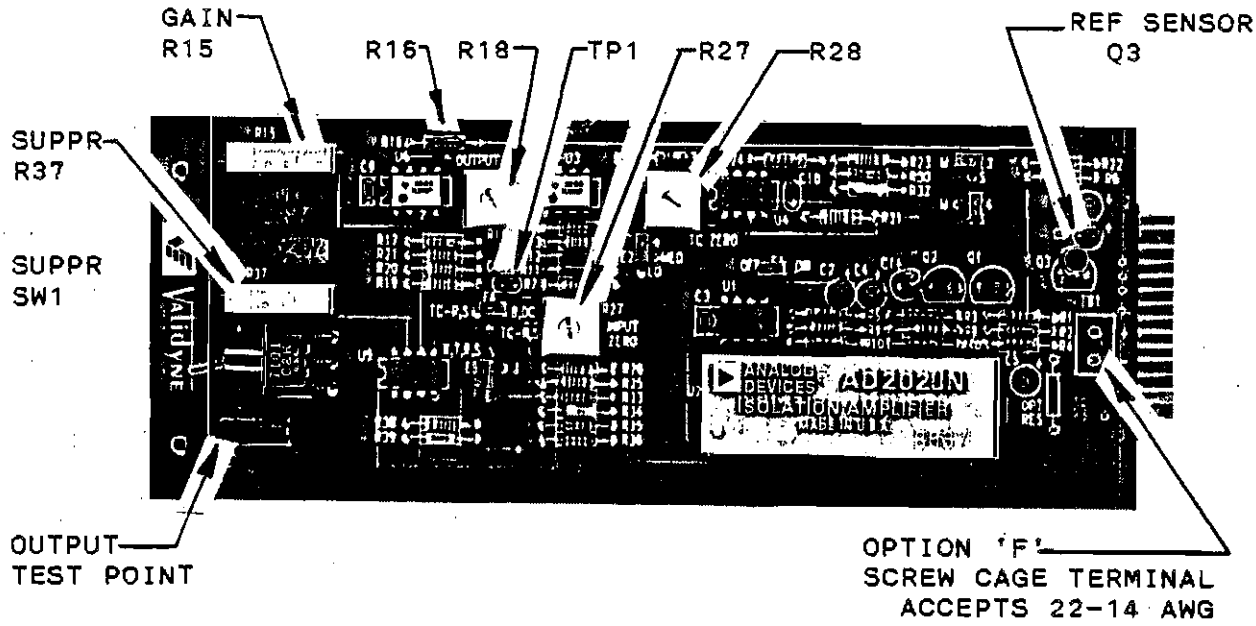


Figure 1-1: TC387 Front Panel



TERMINAL OPTION		TC387 F
F	FRONT PANEL	
* R	REAR PANEL	

* = STANDARD

Figure 1-2: Component Layout

2. INSTALLATION AND OPERATION

2.1 INSTALLATION

The TC387 may be installed in any slot of the MC170 family of module cases:

MC170
MC170T (Option A)*
MC170-32
MC370AD-Q2
MC374AD
DAS932
MC308 (Option A)*

*NOTE: Other options such as C or E may be used if external reference junction sensing is not required.

The tabulation below gives the card-edge pin functions of the TC387. Note the even number pins are on the component side of the PCB (printed circuit board) with pin 2 starting at the top and pin 30 at the bottom.

Pin	Function	
7,8	+15Vdc *	
9,10	Power Ground *	
11,12	-15Vdc *	
16	External Sensor	
18	Sensor Return	
20	+ Signal Input	Option R
22	- Signal Input	
23, 24	Signal (Output) Ground *	
25, 26	Output Signal	

* Items marked with asterisks are bussed to all slot positions in the module case. The power ground and signal (output) grounds are tied together at the module case power supply.

2.2 INPUT-OUTPUT CONNECTIONS

Figure 2-1 shows the connections for input and output when the TC387 is inserted into the MC170T or MC308T module cases. The internal module case wiring must be OPTION A to obtain the connections shown in Figure 2-1. If the remote external reference junction sensor is not used, then OPTION C or E module case wiring could be used for operation of the TC387. A table of the MC170T and MC308T wiring options is shown in Table 2-1.

The MC170-32 and DAS932 input connections for use of the TC387 are shown in Figure 2-2. The signal output connections for those two module cases are shown in Figure 2-3.

An example of a remote reference junction sensor hookup is shown in Figure 2-4. This capability of the TC387 can provide real economy since thermocouple wiring lengths can be reduced. The thermocouple-to-copper transition should be protected from rapid temperature changes - shield the terminal blocks from drafts and direct sunlight if possible. Locate the remote reference junction sensor (2N2222 transistor) close to the thermocouple-to-copper transition point on the remote terminal block.

The instruction manual for the particular module case should be consulted for additional information on making wiring connections.

2.3 THERMOCOUPLE REFERENCE JUNCTION COMPENSATION

The TC387 has been designed to provide reference junction ambient temperature compensation for most popular types of thermocouples. The list below indicates the thermocouple type and polarities of input sense, plus the applicable compensation signal slope:

TYPE	+MATERIAL	-MATERIAL	REFERENCE JUNCTION SLOPE
E	Chromel	Constantan	34μV/°F
J	Iron	Constantan	29μV/°F
K	Chromel	Alumel	22.6μV/°F
T	Copper	Constantan	22.6μV/°F
R	Platinum	Plat., 13% Rhod.	3.25μV/°F
S	Platinum	Plat., 10% Rhod.	3.25μV/°F
B	Plat., 6% Rhod.	Plat., 30% Rhod.	±0.1μV/°F

Jumpers are provided on the TC387 to make selection of the proper reference junction compensation easy to accomplish. See Table 2-2 for positions of jumpers to compensate for various types of thermocouples.

2.4 THERMOCOUPLE OPEN CIRCUIT DETECTION

A current source can be jumped at the input to the TC387 such that an open circuit thermocouple connection will drive the TC387 to positive saturated output. Jumper E1 has two positions: ON and OFF. When E1 is in the ON position, a current of 80 nano-amperes is superimposed on the + Signal Input lead to the TC387. This current is low enough to not create a significant input error when reasonable source resistance thermocouple wiring is attached.

If this current is too high for the application, the current may be disabled by positioning E1 to the OFF position. The result from an open circuit input is typically near zero voltage referred to the input pins, which means the output could remain on-scale with an open input wiring condition.

Rear Panel Terminal Block	Card Edge Connector Pin No.	Function
1	16	Ext. Sensor
2	18	Sensor Return
3	20	+ Sig. In *
4	22	- Sig. In *
5	26	Output
6	24	Output Ground
7	28	No Connection

* (TC387R)

Figure 2-1: MC170T(A), MC308T (A) Connections

Input Conn. Plug	Card Edge Connector	Function
1	16	Ext. Sensor
2	18	Sensor Return
3	20	+ Sig. In *
4	22	- Sig. In *
5	19	No Connection
6	21	No Connection
7	28	No Connection

* (TC387R)

Figure 2-2: MC170-32, DAS932, MC374AD Input Connections

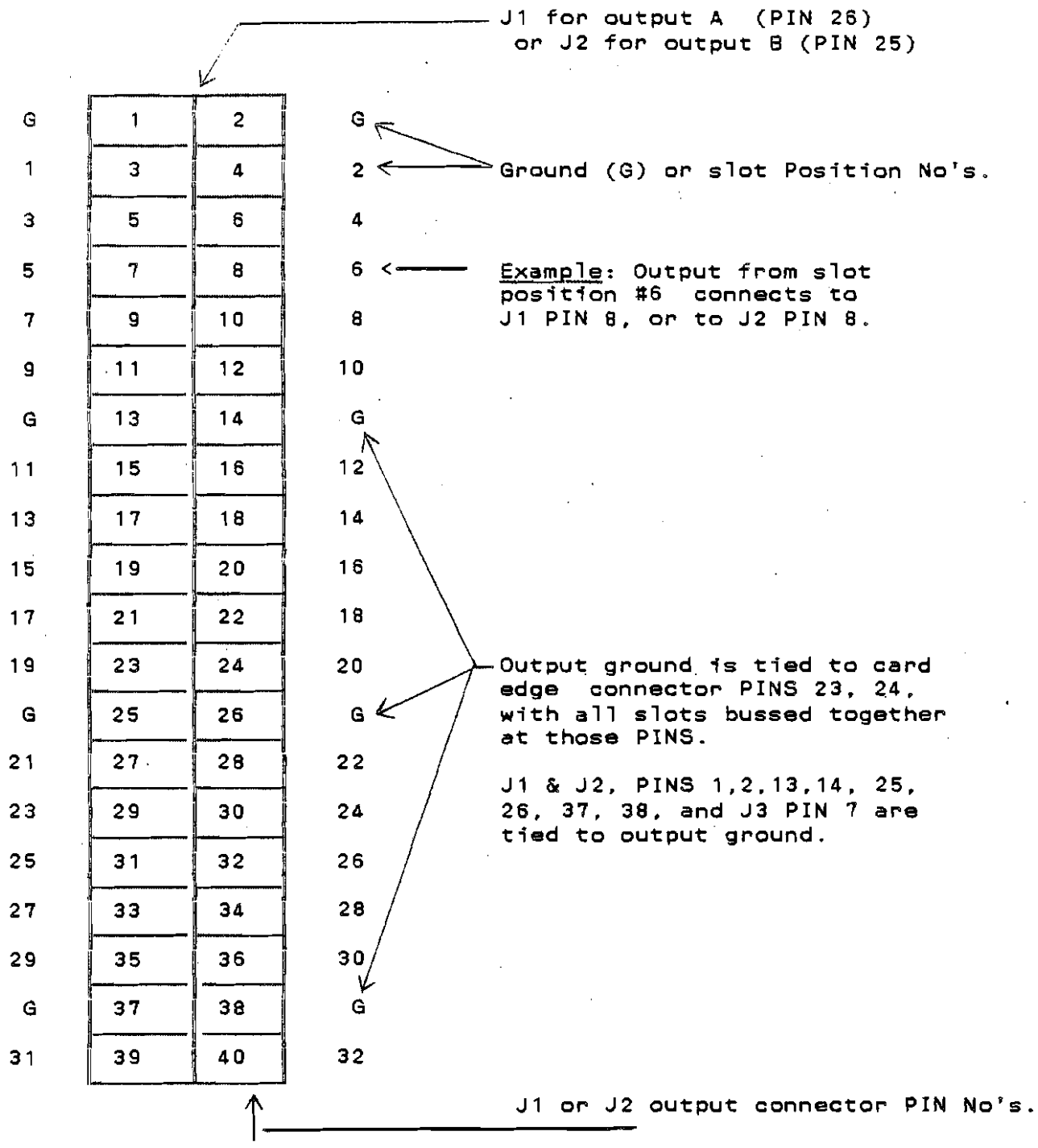
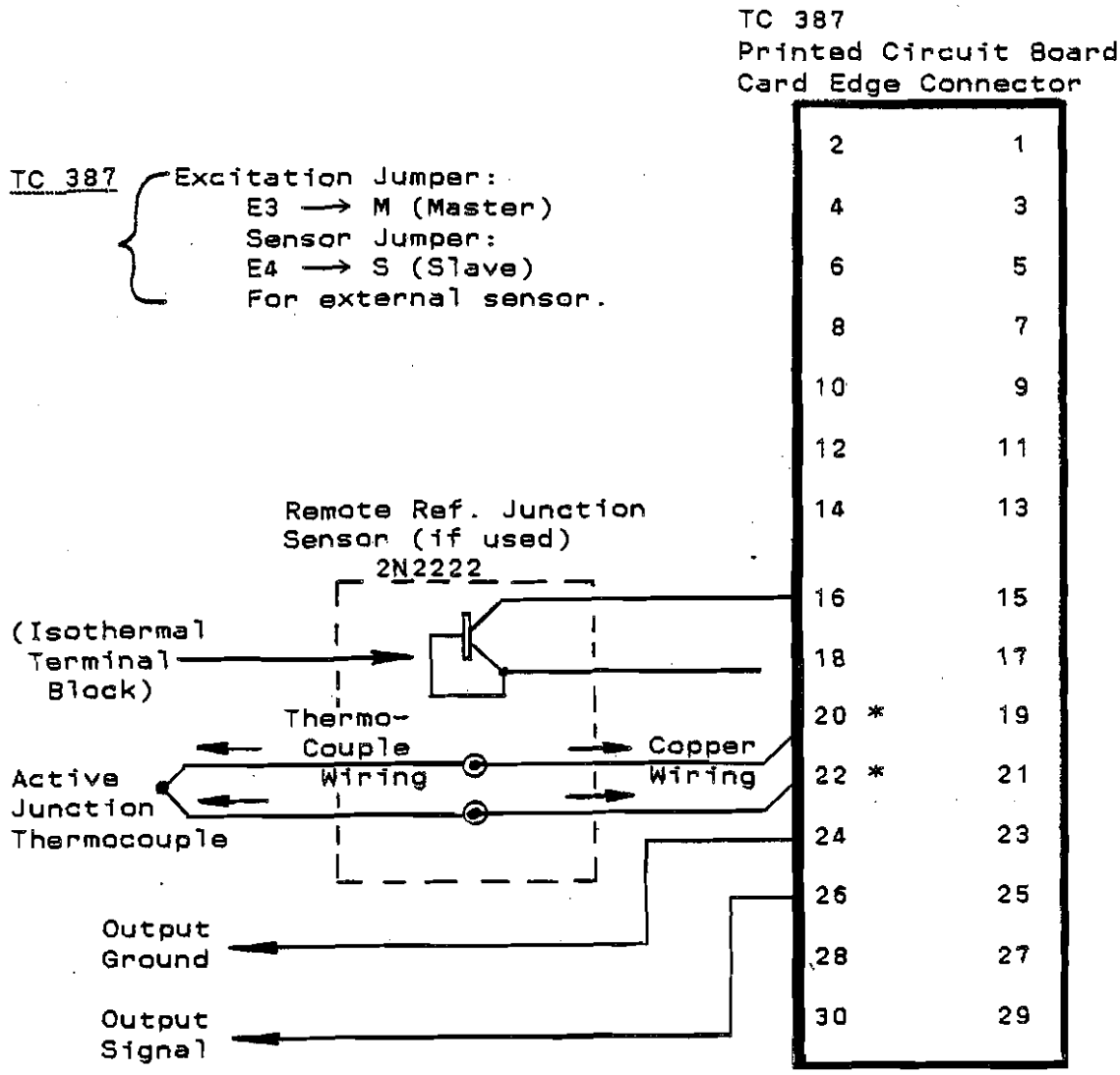


FIGURE 2-3: MG170-32, DAS932, MC374AD OUTPUT CONNECTIONS



* (TC387R)

FIGURE 2-4: MC170 WIRING - REMOTE REF. JUNCTIONS SENSOR

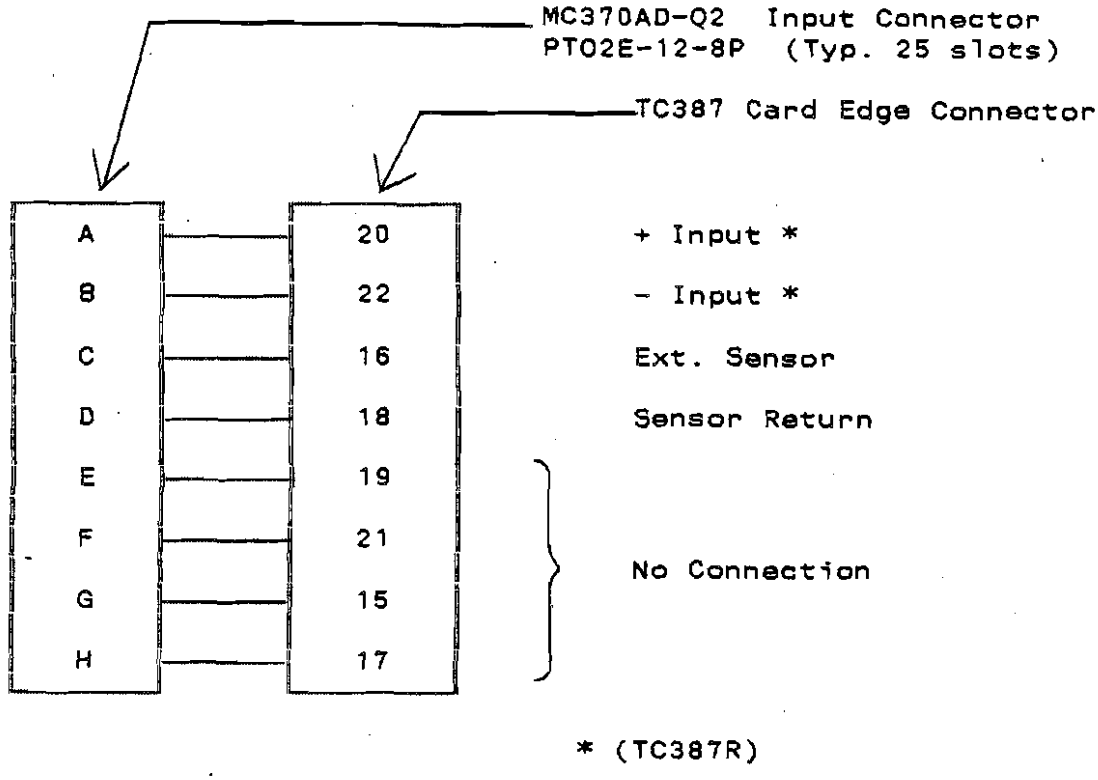


FIGURE 2-5: MC370AD-Q2 INPUT CONNECTIONS

MC170T Only

Terminal Block Pin No.	Option A Card Edge Pin No.	Option B Card Edge Pin No.	Option C Card Edge Pin No.	Option D Card Edge Pin No.	Option E Card Edge Pin No.	
1	16	16	20	14	20	(3*)
2	18	18	22	20	24	
3	20	20	19	22	22	
4	22	19	21	28	28	(1*)
5	26	26	26	27	26	
6	24	23	23	23	27	
7	28	25	25	29	29	

Slot 1 - 24

*Slot 25 only

NOTE: Option B is not suitable for TC387R, but can be used for TC387F.

Table 2-1: MC170T, MC308T Wiring Options

THERMOCOUPLE INPUT TYPE	JUMPERS	
	E5	E6
E	E	TC-$\overline{R}$,$\overline{S}$
J	J	TC-$\overline{R}$,$\overline{S}$
K,T	K,T,R,S	TC-$\overline{R}$,$\overline{S}$
R,S	K,T,R,S	TC-R,S
B,DC*	* *	B,DC

* DC represents non-compensated copper wiring input, as in a DC voltage amplifier mode.

** E5 position may be any of the above (don't care)

Table 2-2: Reference Junction Compensation

3. OPERATION

3.1 THEORY OF OPERATION

A functional block diagram is shown in Figure 3-1. In this figure the signal source is shown as a thermocouple tied to the input pins, 20 and 22, of the TC387. E1 is a jumper which can superimpose a small current through the thermocouple such that an open circuit thermocouple will saturate the amplifier. That would be the indication of an abnormal signal input condition. If E1 is in the OFF position, an open circuit thermocouple would most likely create an on-scale output indication which is not so likely to be noticed.

The first amplifier U1 is a chopper-stabilized amplifier with an input offset voltage less than 30 microvolts. This stage provides a non-inverting voltage gain of 51. The module U2 provides impedance isolation between the input signal and the output common along with isolated excitation power for operating U1, and a unity gain voltage buffer to drive amplifier U3.

Two signals are summed with the output of U2. These are an input zero (R27) and a reference junction compensation voltage derived from U4. The input zero corrects for U1 and U2 offset voltage, and the R28 TC zero adjustment calibrates the reference junction compensation voltage offset error. Selection of the suitable compensation voltage scaling is accomplished by jumper E5 and E6 in accord with Table 2-2.

Table 3-1 shows the gain range selection in amplifier U3 using jumper E2 to choose HI, MED, or LO gain range. These settings give nominal overall gain of 1000, 500, or 250 respectively. A suppression signal is adjusted by R37, and enabled by SW1 to sum at the output of U3 into the last amplifier stage U6. The gain vernier at U6 gives a 0.35 to 1.1 multiplier for the overall gain. R18 provides an output amplifier offset voltage adjustment.

When properly calibrated the R27 and R18 controls allow gain range (E2) and gain vernier (R15) adjustments without significant zero interaction. Similarly, when R28, TC Adjust, is correctly calibrated, the E5 and E6 jumpers can be selected without need to reset R28. These calibration adjustments are described in Section 4. Table 3-4 gives the test point TP1 voltages as a function of ambient temperature.

Remote reference junction sensing is possible by positioning E3 to master position, E4 to slave position, and locating a Q3 transistor between pins 16 and 18 as shown in Figures 2-4 and 3-1.

Most applications use the local on-board sensor, Q3, for sensing the temperature in generating the reference junction compensation voltage. Note that the Q3 sensor location is near the card edge connector, see Figure 1-2, whereas the actual thermocouple to copper transition is at the rear of the module case (for the TC387R model.) If a particular installation creates a significant temperature gradient between these two locations an improvement can be gained by one of the two alternatives:

(1) Use the TC387F model, in which the thermocouple entry is via an insert bushing on the front panel to a terminal block (TB1) directly next to the sensor Q3. This model also disconnects the pin 20 and 22 module case wiring from the + input and -input points of the TC387, which permits up to ±200 Vdc, or 125Vac 60Hz voltage to be applied as a common mode voltage on the input.

(2) Use an external reference junction sensor at the same location as the thermocouple-to-copper transition. This can be at the rear of the module case, or at a location more remote from the TC387 as desired. See Figures 2-4 and 3-1.

3.2 ZERO AND GAIN CALIBRATION

The easiest method for setting the zero and gain adjustments for the TC387 is to first calculate the needed span and make the adjustments using a precision dc signal source at the input. As an example, if a type E thermocouple is to be used between $0^{\circ}F$ and $1000^{\circ}F$, and the TC387 is to provide 0 Vdc at $0^{\circ}F$ and +10.0 Vdc at $1000^{\circ}F$, the gain is calculated: (See Figure 3-2)

Type E TC output @ $0^{\circ}F$ = -1.026 mV
@ $1000^{\circ}F$ = 40.056 mV

Total = 41.082mV

Span = $\Delta Eo/\Delta E_{in}$ = 10V/41.087mV = 243.4 V/V

The gain range jumper E2 is chosen from the Table 3-1 to be LO range.

First, calibrate the gain using the following steps:

1. Set the open TC detector jumper E1 to the OFF position.
2. Set the gain range jumper E2 to the LO position.
3. Configure the TC387 for DC mode (E6 -->B,DC).
4. Disable the Suppression input (SW1 --> OUT).
5. Apply 0.00mVdc at pin 20 with respect to pin 22 of TC387. Verify the output test point voltage is zero ±0.03Vdc. (Review procedure in section 4.1 if this step has excessive voltage.)

6. Apply 41.00 mVdc at pin 20 with respect to pin 22 of TC387. Adjust the Gain control R15 to obtain +9.98 ±0.03 Vdc at the output test point.
7. Repeat step 5 and 6 until no further adjustment is required.

Next, set the offset (zero suppression) using the following steps:

1. Enable the suppression control by placing the suppression switch SW1 to the IN position.

2. Apply -1.026mV at pin 20 with respect to pin 22 of TC387. Adjust the suppression control R37 to obtain 0.00 ±0.03 Vdc at the Output test point.

Finally set up the TC387 for use with the type E thermocouple as follows:

1. Select type E thermocouple by placing E5 in the E position, and E6 in the TC - R,S position.

2. If the "on board" Q3 reference junction sensor is to be used, place E3 in the M (master) position and E4 in the M (Master) position.

3. If an external reference junction sensor is to be used, place E3 in the M (master) position, and E4 in the S (Slave) position. This provides the sensor excitation current from the TC387, but uses the external sensor as the reference junction temperature signal.

4. Connect the actual thermocouple wiring to the TC387 input circuit. This can be done at an external terminal block at the rear of the module case, or via the front panel of the TC387-F. The reference junction sensor location should be chosen to sense the temperature at this transition point from thermocouple to copper.

5. Measure the temperature at the active thermocouple location. Using the thermocouple tables, look up the thermocouple signal voltage for that temperature. In our example, illustrated in Figure 3-2, assume the active thermocouple is measured to be at 100°F. The type E thermocouple signal is 2.281 mV per the TC tables. The input signal change from 0°F to 100°F is 3.307mV, which gives a 0.805Vdc output after the gain of 243.4V/V. If the output is greater than ±0.05Vdc away from the calculated value of 0.805Vdc, the reference junction Tc zero control R28 needs readjustment as described in section 4.2.

3.3 ZERO SUPPRESSION

The TC387 design provides an output zero elevation or suppression of up to ±10Vdc. This function is enabled by the front panel SUPPR switch SW1 = IN, and the amplitude is adjusted by SUPPR control R37 via the front panel.

Figure 3-3 shows the suppression control effect on the transfer function. The A-lines show the effect of gain adjustments without suppression. The B-line show the output elevated, and C-lines show the output suppressed. Note that gain adjustment causes the set of lines to pivot about the zero input vertical line.

During setup of the TC387, calibration is most efficient if suppression is first adjusted (with the input at zero) and then the gain is adjusted with an end scale input applied. This procedure will minimize interaction between the controls and produce precision results in the least time.

As an example of this procedure, assume the transfer function shown in Figure 3-4 is desired. A dc amplifier is to provide 0Vdc output with +0.01Vdc at the input and +10Vdc output with +0.05Vdc at the input. The gain is calculated to be 250 V/V, and the Y-axis intercept is calculated to be at -2.5Vdc.

From our knowledge about Figure 3-3, we can see that gain adjustment will pivot the line about the Y-axis intercept. The place to start is by adjusting the suppression for an output of -2.5Vdc when the input is zero. The set up and procedure is as follows:

1. Set jumper:
   E1 = OFF
   E2 = LO (per Table 3-1)
   E3, E4, E5 = don't care (DC amplifier, not TC input)
   E6 = B, DC

2. Apply 0.00 ±0.01 mVdc at pin 20 with respect to pin 22. Adjust SUPPR control, R37, to obtain -2.50 ±0.03Vdc at the OUTPUT test point.

3. Apply +50.0 mVdc at pin 20 with respect to pin 22. Adjust the GAIN control R15, to obtain +10.00 ±0.03Vdc at the OUTPUT test point.

4. Apply +10.0mVdc at pin 20 with respect to pin 22. Verify the OUTPUT test point reads 0.00 ± 0.03 Vdc. If necessary, repeat steps 2 and 3 to satisfy step 4.

3.4 OPERATION AS DC AMPLIFIER

The TC387 may be used as a high gain dc isolation amplifier by disabling the reference junction compensation circuit. AS shown in the suppression example in section 3.3, the setup jumpers should be:

1. E1 = OFF
2. E2 = As determined in Table 3-1
3. E3, E4, E5 = don't care (DC, not TC input)
4. E6 = B, DC (To disable reference junction signal)

The suppression IN/OUT choice is made with the front panel switch. Calibration is done as in previous examples. Adjust suppression (if used) while the input signal is zero. Next adjust the gain control with a full scale signal applied at the input. It is a good practice to verify linearity by checking say a mid scale point in addition to the zero and full scale points.

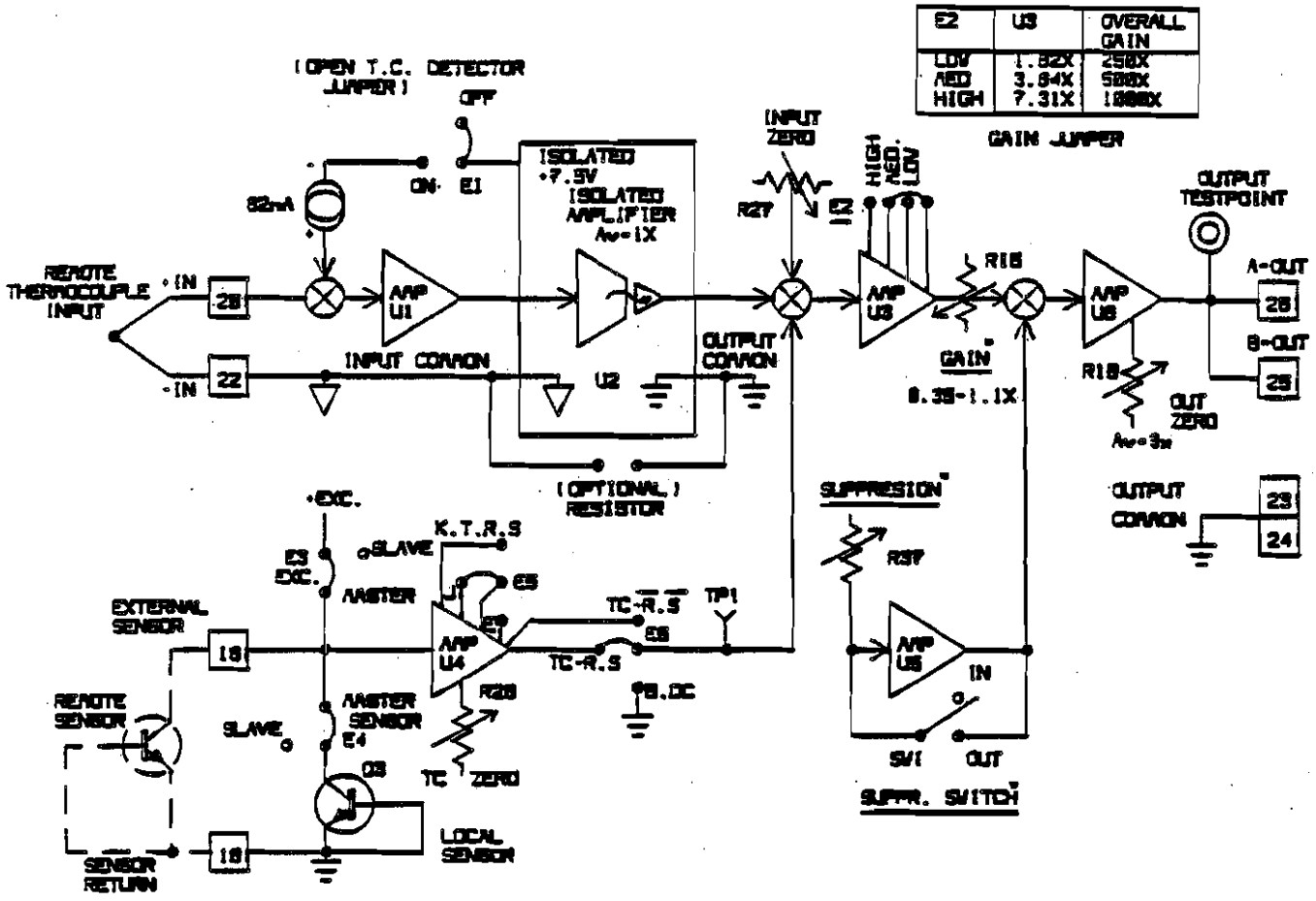


Figure 3-1: TC387 Functional Block Diagram

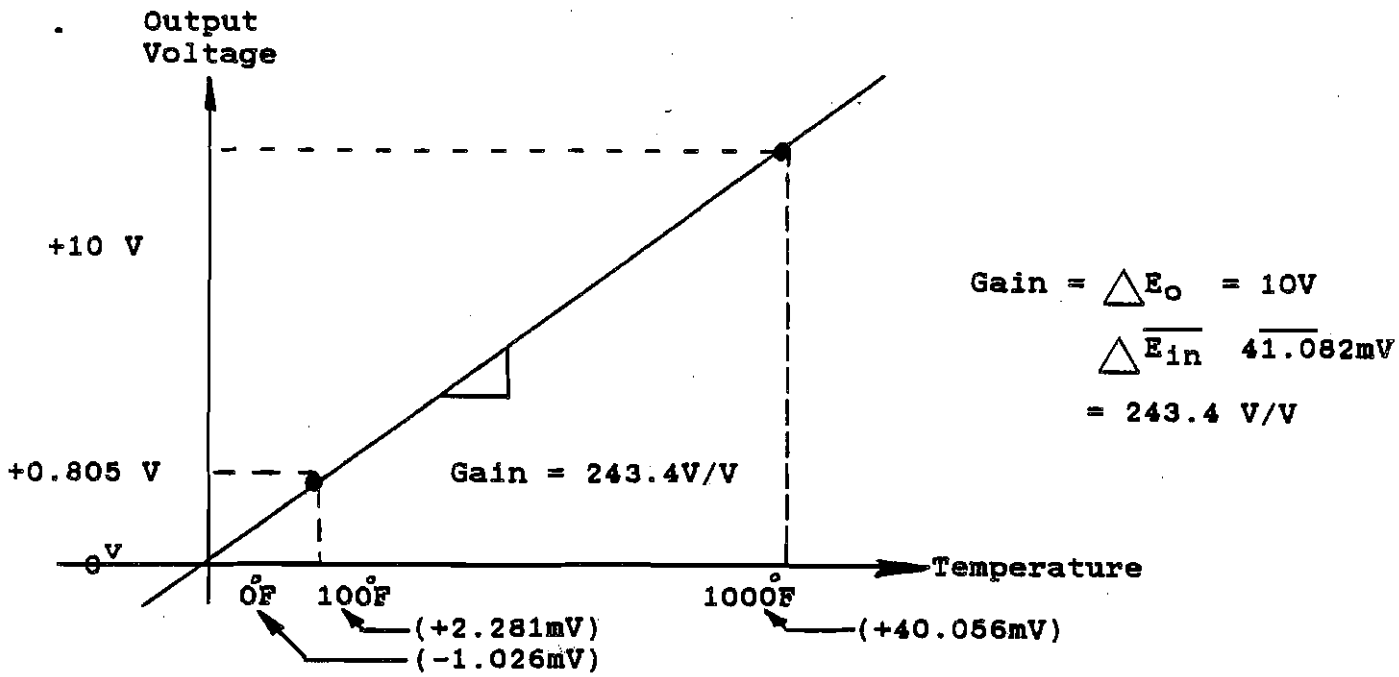


Figure 3-2: Zero and Gain Calibration Example

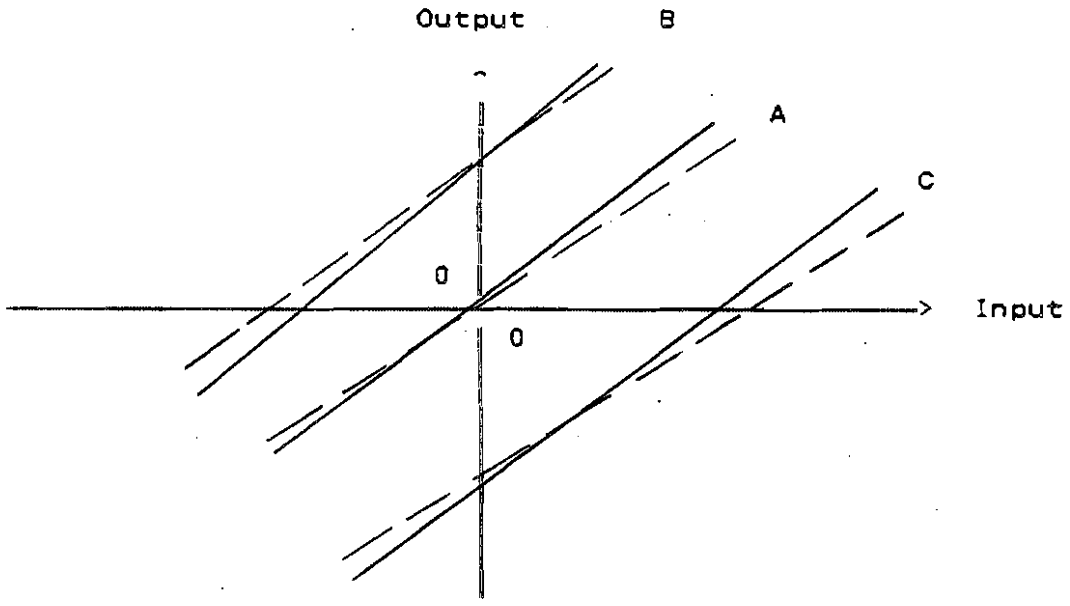


Figure 3-3: Output Suppression Characteristics

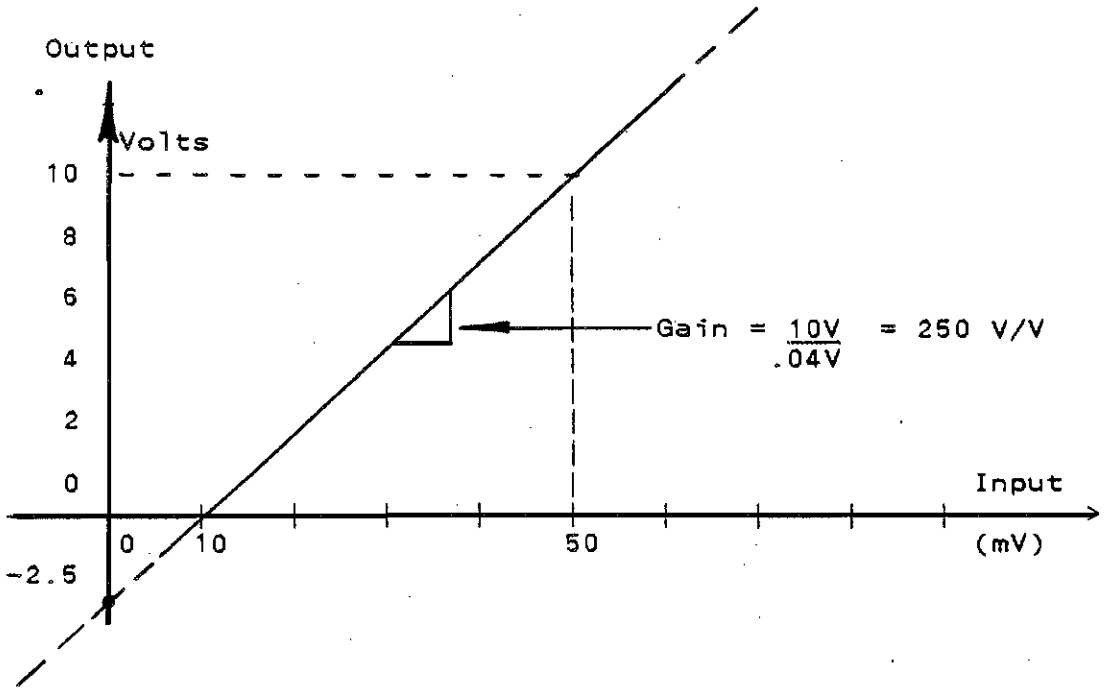


Figure 3-4: Suppression Example

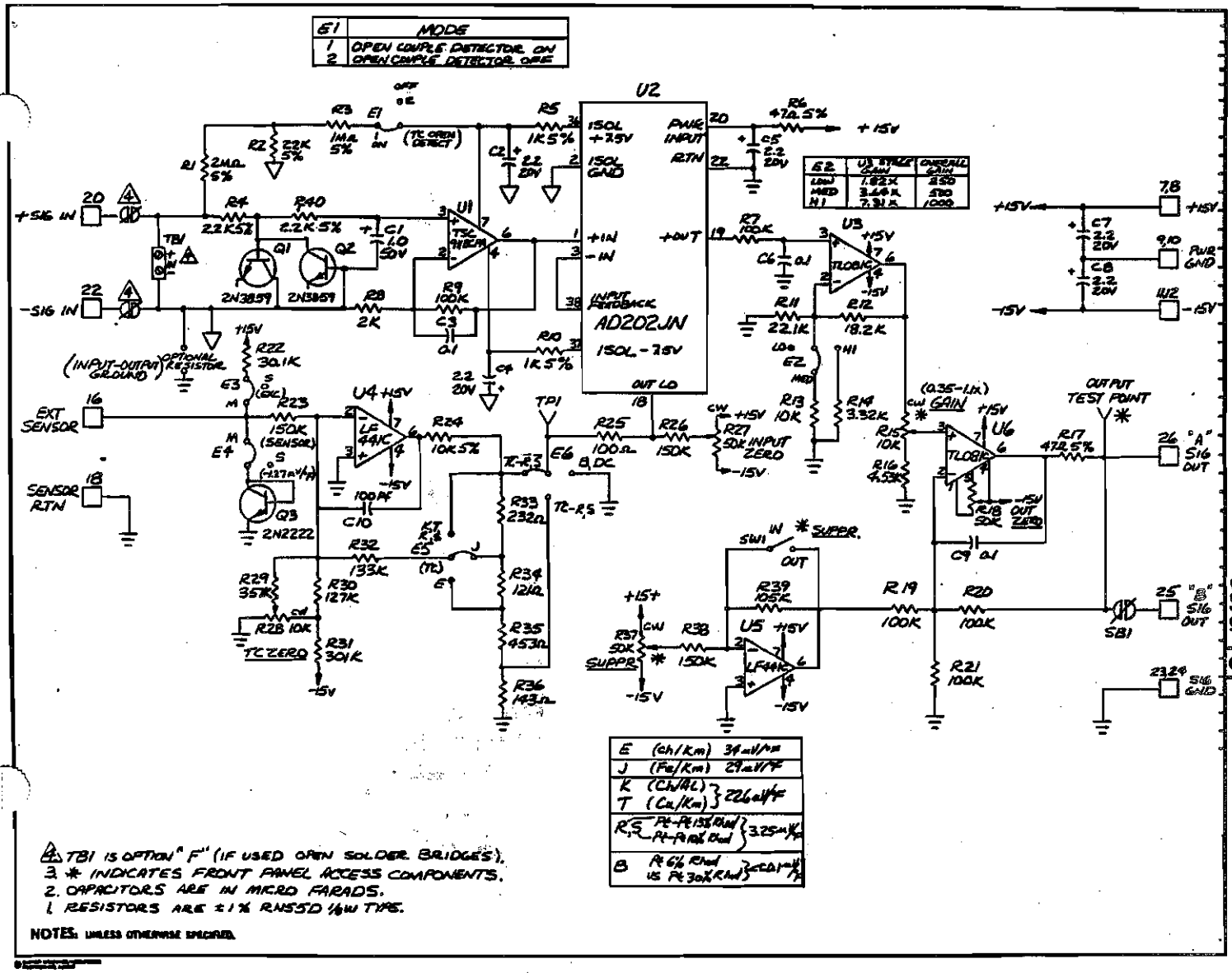


Figure 3-5: TC387 Schematic Diagram

JUMPER E2 POSITION	TC387 OVERALL GAIN RANGE
LO	88 - 275
MED	180 - 550
HI	350 - 1100

If the desired gain is in the overlap region, better adjustment stability is obtained using the lower gain range. For example, if the desired gain is 500, plan to place E2 in the MED position.

Table 3-1: Gain Range Jumper Selection

THERMO-COUPLE TYPE *	TEST POINT (TPI) VOLTAGES (mVdc) AMBIENT TEMPERATURE (°F)								
	68	70	72	74	76	78	80	82	84
E	62.4	65.9	69.4	72.8	76.3	79.8	83.2	86.7	90.2
J	53.2	56.2	59.2	62.1	65.1	68.0	71.0	74.0	76.9
K,T	41.5	43.8	45.1	48.4	50.7	53.0	55.3	57.6	59.9
R,S	5.97	6.30	6.63	6.96	7.29	7.62	7.96	8.29	8.62

(*See Table 2-2 for Jumper Positions)

Table 3-2: Reference Junction Compensation Calibration

4 MAINTENANCE AND REPAIR

The TC387 is designed to permit convenient front panel access to calibration adjustments. The three potentiometers R18, R27, and R28, which are not accessible through the front panel, are factory-set controls for Output Zero, Input Zero, and TC Zero respectively. These typically do not need to be periodically reset. Instructions for their adjustment are included below in the event of repair or accidental misadjustment.

4.1 INPUT ZERO AND OUTPUT ZERO ADJUSTMENTS

Position the jumpers as follows:

1. E1 = OFF
2. E2 = HI
3. E3, E4, E5 = don't care
4. E6 = B, DC

A. Apply a jumper from pin 20 to pin 22.
Monitor the dc voltage across R16 (see Figure 1-2).
Adjust the INPUT ZERO control, R27, to obtain 0 ±0.002 Vdc across R16.

B. Place the SUPPR switch SW1 = OUT.
Monitor the Output test point dc voltage.
Adjust the OUTPUT ZERO control R18 to obtain 0.00 ±0.01 Vdc at the Output test point.

4.2 TC ZERO ADJUSTMENT

Verification of the reference junction temperature compensation signal requires a thermometer to measure the ambient temperature next to the sensor, Q3. If an external sensor is to be used, the temperature at the sensor location must be measured.

Table 3-4 gives the value of the signal at test point TP1 (see Figure 1-2 for location) for ambient temperature ranging from 68° to 84°F.

In addition to correctly positioning the jumpers E5 and E6 in accord with Table 2-2, the jumpers E3 and E4 must be placed as appropriate to use the local or the remote temperature sensor (see Section 3.1).

After choosing the positions for E3 - E6, operate the TC387 for a few minutes to obtain stable warmed-up conditions. No connections to the input are needed for this test. Monitor the ambient temperature at the reference junction sensor. Avoid drafts or unstable temperatures during this test. Read the dc voltage at TP1 and compare it with the value shown in Table 3-4 corresponding to the measured ambient temperature.

If the error observed above is in excess of $\pm 3^{\circ}F$, the TC ZERO control, R28, may be adjusted to provide the correct readings.

4.3 FIELD SERVICING HINTS

Avoid contaminating the electrical contact surfaces - the card edge connector and the contact-posts engaged by jumpers E1-E6. The jumper contacts should be securely inserted. Take care to not lose any of the push-on jumpers. Use only a 0.080 inch diameter probe in the front panel OUT test point to avoid spreading the contact.

4.4 REPAIR

If abnormal performance cannot be corrected using the calibration and adjustment procedures outline in this manual, return the unit to the factory for evaluation and repair. All repairs must be sent transportation PREPAID.

Please see Warranty and Repair Policy information sheet at the front section of manual.