TC453
Thermocouple Amplification Module

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SECTION 1

1.0 DESCRIPTION

1.1 Introduction

This technical manual contains installation and operating instructions for a Model TC453 Thermocouple Amplifier Plug-In Module for the MC1 Multi-Channel module case. The Module and Module Case are manufactured by Validyne Engineering Corporation, Northridge, California, 91324.

1.2 General Description

The TC453 thermocouple Amplifier is a plug-in module for the MC-1 Multi-Channel Modular System. The TC453 module comes either in an input/output isolated version (TC453A2) or a direct-coupled version (TC453A). Both modules provide a 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.

Internal jumpers provide a selection of cold junction compensation for the type of thermocouple used and enable thermocouple open circuit detection.

Front panel controls provide vernier gain, zero suppression and a low pass filter selection of 0-1Hz, 0-3Hz, or 0-10Hz frequency response.

Two front panel test points are provided. The output test point supplies the output voltage for tests and adjustments. The suppression test point measures the DC zero suppression voltage.

Input and output connections are made 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 TC453 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.

All power requirements for the operation of the TC453 are supplied by the MC-1 Module Case.

1.3 Technical Characteristics

The technical characteristics are shown below in Table 1.

Table 1 - Technical Characteristics

PARAMETER	SPECIFICATION
Input Signal Range:	+9mV FS to ±100mV FS for ±10V Full Scale Output
Gain Range Selection:	3-position switch (input range): High Gain (9mV to 25 mV) 1000X Med Gain (18 mV to 50mV) 500X Low Gain (36 mV to 100mV) 250X.

Gain Adjustment Potentiometer: Continuous adjustment from 40% to 110%, 20 turn pot.

Zero Suppression: 20 turn potentiometer for ±10Vdc output suppression, enabled with In/Out switch.

Common Mode Rejection Ratio: ≥100dB at dc to 60 Hz Differential gain of 1000.

Cold Junction Compensation: Jumper selectable for types E, J, R, S, B, K and T.

Cold Junction Compensation Error: **Front Panel Thermocouple Entry**: 1°F for ±10°F ambient temperature change. **Rear Panel Thermocouple Entry**: 5°F for ±25°F ambient temperature change.

Thermal Effects: (DC Amplifier) Span 0.005%/° F typical Zero 0.5μV/°F referred to input.

INPUT CHARACTERISTICS

Input to Output Isolation: **Isolated Version**: >100Meg ohms at ±100Vdc between input and output. Same, at ±200Vdc.

Direct-Coupled Version: +7.5 Vdc common-mode range with 1M ohms common mode input resistance.

Safe Differential Voltage: ±20V

Differential Input Impedance: **Isolated Version**: 2 Meg ohms, paralleled by 1.0 microfarads (limited by silicon diodes and 2.2 K ohms resistor above ±0.6V).

Direct-Coupled Version: ≥1 Meg ohms in parallel with 0.018 microfarads.

OUTPUT TO CHARACTERISTICS

Output Voltage: ±10 Vdc @ 5 mA maximum, short circuit proof, not affected by line capacitance.

Output Resistance: 10 Ohms maximum.

Output Noise: 5mVrms at maximum gain.

Linearity Power Consumption: 0.05% FS, linear amplifier. +15 V @ 12 mA. -15 V @ 7 mA.

FRONT PANEL CONTROLS

Gain Control (R16, SW1): A screwdriver operated potentiometer for vernier gain adjustment, plus a toggle switch for overall gain.

LO = 250
MED = 500
HI = 1000

Suppression (SUPPR): (R25, SW2) A screwdriver-operated potentiometer for output zero suppression or elevation, plus a toggle switch for in/out suppression mode selection.

Low Pass Filter Switch (S3): A switch for selecting 1Hz, 3Hz, or 10Hz frequency response.

Test Points: **OUT (TP1)**: Measures the output voltage for tests & adjustments.
GND (TP2): Ground Return.
SUPR (TP4): Measures the DC Zero Suppression Voltage.

INTERNAL CONTROL/JUMPERS.

Input Zero(R42): A screwdriver operated single turn potentiometer for nulling the input amplifier offset voltage.

Output Zero (R14): A screwdriver operated single turn potentiometer for nulling the output amplifier offset voltage.

T.C. Zero (R59): A screwdriver operated single turn potentiometer for offset corrections of the TC references amplifier.

Jumper E1 (Isolated version): Open circuit thermocouple Detector.
On= Detector ON
OFF= Detector OFF

Jumper E2: Excitation Master/Slave.
M = Master
S = Slave.

Jumper E3: Sensor Master/Slave.
M= Master
S= Slave.

Jumper E4: Thermocouple Type/Mode.
TC - R,S = R or S type TC.
TC - /R,/S = not R or S type TC.
B, DC = B type TC or no TC (=DC)

Jumper E5 Thermocouple Type Selection.
K,T,R,S = Type of TC
J = Type of TC
E = Type of TC

Jumper E6 (Direct-coupled version): Open circuit thermocouple Detector.
ON = Detector ON
OFF = Detector OFF

SECTION 2

2.0 INSTALLATION

2.1 Installation

The Model TC453 Thermocouple Amplifier Module may be plugged into or out of any available channel of the MC1 Module Case while power is on without damage and without affecting adjacent channels.

2.2 Input - Output Connections

The tabulation below gives the card-edge pin functions for the TC453. Items marked with asterisks are bussed to all slot positions in the MC1 module case. The Power Ground and Signal (output) Grounds are tied together at the MC1 Module Case power supply.

TABLE 2 - INPUT / OUTPUT CONNECTIONS

PIN	Function
3	+15Vdc*
4	+ Signal Input
7	-15Vdc*
8	- Signal Input
9	Power Ground*
10	Sensor Return
11	External Sensor
12	"A" output Signal
14	"B" output signal
15	Signal (Output) Ground

2.2.1 Front Panel Input Connections

The following procedure applies to connection of thermocouples:

A. Route the leads of the thermocouple through the grommet on the front of the panel.

B. Connect the leads to the screw-clamp terminals on the circuit board. Make sure that the positive lead goes to the No. 1 position on the terminal, and the negative lead to the No. 2 position.

C. Secure leads to screw-clamp terminals by cinching up screws.

2.2.2 Remote Reference Junction Sensor Hookup

A design provision for attaching the temperature input for remote temperature compensation is present on the TC453. An example for the 7-screw barrier-type terminal strip is shown in Figure 1. For the cannon WK-4-325, Figure 2 illustrates the remote sensor hook-up. This capability of the TC453 can provide real economy since thermocouple wiring lengths can be varied. The thermocouple-to-copper transition should be protected from rapid temperature changes by shielding the terminal blocks from the drafts and direct sunlight. Locate the remote reference junction sensor (2N2222 transistor) close to the thermocouple-to copper transition point on the remote terminal block.

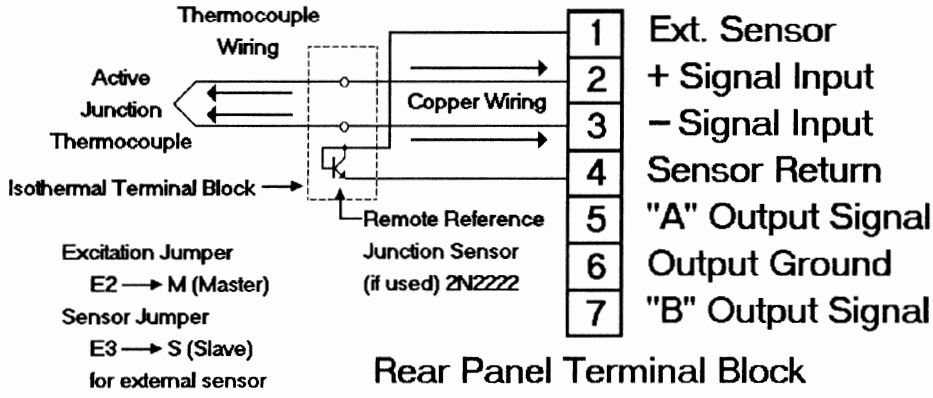

Figure 1 - MC1 Wiring - Remote Reference Junction Sensor for 7-screw barrier type terminal strip.

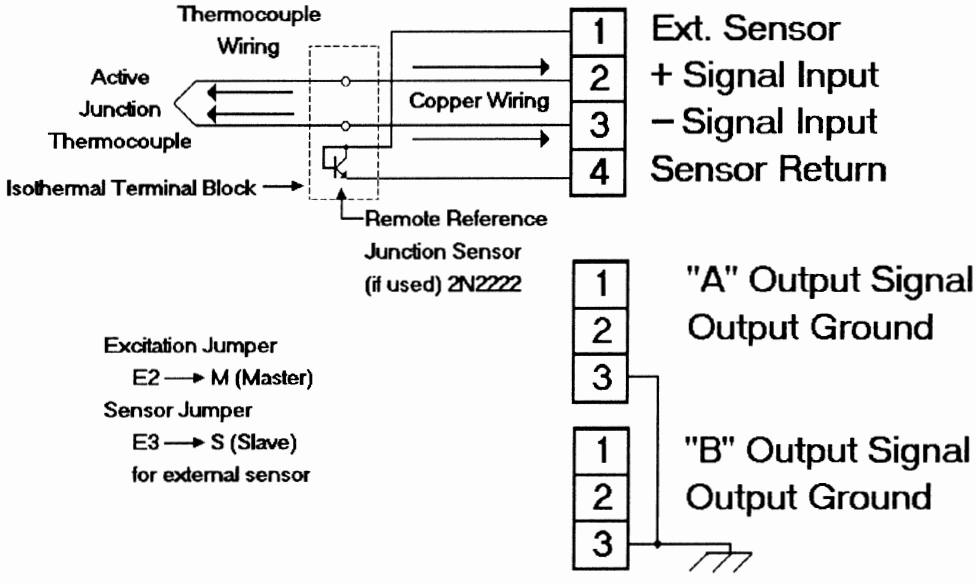

Figure 2 - MC1 Wiring - Remote Reference Junction Sensor for Cannon WK-4-21C input connector.

2.3 Thermocouple Reference Junction Compensation

The TC453 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

TABLE 3 - Thermocouple Types

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.	3.25 μV/° F
B	Plat., 6% Rhod.	Plat., 30% Rhod.	±0.1μV/°F

Jumpers are provided on the TC453 to make the selection of the proper reference junction compensation easy to accomplish. See Table 4 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 TC453 such that an open circuit thermocouple connection will drive the TC453 to positive saturated output. Jumper E1 (E6, direct coupled version) has two positions: ON and OFF. When E1 (E6) is in the ON position, a current of 80 nanaoamperes is superimposed on the + Signal Input lead to the TC453. 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 (E6) to the OFF position. The result from an open 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.

TABLE 4 - Reference Junction Compensation Selection

THERMOCOUPLE INPUT TYPE	JUMPERS E5	JUMPERS E4
E	E	TC, $\overline{R}$, $\overline{S}$
J	J	TC, $\overline{R}$, $\overline{S}$
K or T	K, T, R, S	TC, $\overline{R}$, $\overline{S}$
R or S	K, T, R, S	TC, R, S
B or 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 (doesn't care).

SECTION 3

3.0 OPERATION

3.1 Zero and Span Calibration

Table 4 lists the jumper positions for types E,J,K,R,S,B, and T thermocouples. Also shown are the jumper positions for copper wire connections to the MC1 terminals - e.g., wiring from a non- thermocouple signal source. In this case, no internal or external cold junction compensation is used (DC).

Because of their location, these jumpers cannot be repositioned without pulling out the TC453 modules. This can be done with the case power on. If adjustments are to be made with the module operational, a Validyne P/N 8609 Module Extender Card should be used.

3.1.1 Prior to the system calibration with the thermocouple, perform the following steps:

A. Insert Jumpers E2,E3,E4, and E5 into their proper positions for the type of thermocouple used (see table 4).

B. Place switch S2 to the OFF position (zero suppression)

C. Place switch S3 to either 1 Hz, 3 Hz, or 10 Hz frequency response position.

D. Place switch S1 to the desired gain step.

Example: A type J thermocouple is to be used to measure 32° - 1000° F for an output voltage of 0-10 V dc. Full scale input will be approximately 1000° F X 29 μV/°F = 29 mV. Required gain is Eo/Ein = 10V/.029V = 345. Set switch S1 to the MED gain (X500) position.

With the TC453 installed in the MC1 case, the output can be monitored by a DC voltmeter connected to the Output test point and the GND test point on the TC453 front panel.

TABLE 5 - Gain Range Selection

OVERALL GAIN RANGE	SWITCH SELECTION*
88 - 275	LO
180 - 550	MED
350 - 1100	HI

NOTE: If the desired gain is in the overlap region, better adjustment stability is obtained by using the lower gain range setting. For example, if the desired gain range is 500, plan to set S1 to the MED position.

3.1.2 For system calibration, perform the following steps.

A. With a screwdriver, adjust the GAIN potentiometer on the front panel fully clockwise - i.e., maximum output voltage.

B. Insert the thermocouple into an ice-bath (32°F). Output voltage should drop to 0.00 +0.05 V dc.

C. Insert the thermocouple into boiling water (212° F at 14.7 PSIA atmospheric) and adjust the GAIN potentiometer for the desired output voltage at the temperature. Any other known temperature can similarly be used for this step.

D. For optimum accuracy, the zero suppression control (SUPR) can be used to eliminate any zero offset or to scale the output to some other zero reference than 32° F.

Example: A type J thermocouple is to be used to provide 0-10 Vdc output from 0°-1000°F. In this case, since zero output is not to be at 32°F, set the suppression switch S2 to the IN position. With the thermocouple at 32°F adjust the suppression potentiometer on the front panel for an output of 0.32 Vdc. With the thermocouple at 212°F, adjust the Gain for an output of 2.12 Vdc. The channel is now set up to read the temperature directly with an output scale factor of 1 Vdc/100°F.

System calibration can also be performed by using known input voltages taken from standard thermocouple output tables referenced to 32°F.

TABLE 6 - Thermocouple Voltages Vs. Temperature

(Ta) °F	THERMOCOUPLE TYPE E	J	K	R	S	T	B
64	0.0539	0.0462	0.0362	0.0050	0.0051	0.0357	0.00015
66	0.0573	0.0491	0.0384	0.0054	0.0054	0.0380	
68	0.0608	0.0520	0.0407	0.0057	0.0058	0.0402	
70	0.0642	0.0549	0.0430	0.0060	0.0061	0.0425	
72	0.0676	0.0578	0.0453	0.0063	0.0064	0.0448	
74	0.0711	0.0607	0.0476	0.0067	0.0068	0.0471	
76	0.0745	0.0636	0.0499	0.0070	0.0071	0.0494	0.00015
78	0.0780	0.0666	0.0522	0.0073	0.0074	0.0517	0.00010
80	0.0814	0.0695	0.0545	0.0076	0.0078	0.0541	
82	0.0849	0.0725	0.0568	0.0080	0.0081	0.0564	
84	0.0884	0.0754	0.0591	0.0084	0.0085	0.0587	
86	0.0918	0.0783	0.0614	0.0087	0.0088	0.0610	
88	0.0953	0.0813	0.0636	0.0090	0.0091	0.0633	0.00010

NOTE: See Table 4 for jumper positions.

3.2 Zero Suppression

Zero suppression is useful for expanding the output over part of a wide temperature range. For example, if the temperature range of interest is 400° to 500°F, the output can be suppressed to zero at 400°F and the

gain increase to expand the output from 400°-500°F. The front panel SUPPRESSION control on the TC453 provides up to ±100% zero suppression at any gain step, making it possible to suppress or elevate zero. CCW adjustment suppresses zero, CW adjustment elevates to zero. The suppression voltage, variable from ±0 to 10Vdc, can be monitored at the front panel SUPR test point (TP). For the zero SUPPRESSION control to be active, switch S2 must be positioned to the ON position; otherwise, this control will be inactive.

3.3 Operation as DC Amplifier

With jumper E4 inserted in the B,DC position, the output of the cold junction compensation circuit is grounded, allowing the amplifier to be used as a variable-gain DC amplifier. In this situation, the positions of jumpers E2, E3 and E5 will have no effect. The gain switch S1, the filter switch S3, and the zero suppression switch S2 all remain operable with the amplifier in the DC mode.

SECTION 4

4.0 MAINTENANCE AND REPAIR

The TC453 is designed to permit convenient front panel access to calibration adjustments. The potentiometers R14, R42, R59, and R60 (direct coupled version only), which are not accessible through the front panel, are factory-set controls for Output Zero,Input Balance, TC Zero, and Common-Mode Adjustment 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 Adjustment

Position the jumpers as follows:

1. E4 = B,DC
2. S2 = OUT (SUPPR OFF)
3. E1 = OFF (OPEN TC DETECTION)

Isolated Version:

1. Short Input pins 4 and 8 to GND (pin 9).
2. Monitor dc voltage at the TP1 test point.
3. Set the Gain switch S1 to the HI position.
4. Adjust the Output Zero potentiometer, R14, to obtain .01 V dc at TP1.
5. Set the Gain switch S1 to the LO Position.
6. Monitor the dc voltage at U1 pin 7.
7. Adjust the Input Balance potentiometer, R42, to obtain <0.01 V dc at U1 pin7.
8. Monitor the dc voltage the TP1 test point.
9. Set the Gain switch S1 to the HI position.
10. Adjust the Output Zero potentiometer, R14, to obtain <.002 Vdc at TP1.
11. Set the Gain Switch S1 to the LO position.
12. Monitor the dc voltage at U1 pin 7.
13. Adjust the Input Balance potentiometer, R42, to obtain <.002 Vdc at U1 pin 7. Repeat the above steps until no further adjustment is needed.

Direct-Coupled Version (non-isolated):

1. Short Input pins 4 and 8 to Gnd (pin 9).
2. Monitor and dc voltage at U1 pin 7.
3. Adjust the Input Balance potentiometer, R42, to obtain ±0.0005 V dc at U1 pin 7.
4. Monitor the dc voltage at the TP1 test point.
5. Set the Gain switch to S1 to the HI position.
6. Adjust the Output Zero potentiometer, R14, to obtain <.002 Vdc at TP1.
7. Set the Gain Switch S1 to the LO position.
8. The change at TP1 should be <0.01 Vdc.
9. Remove Input pins 4 and 8 from GND.
10. Monitor the dc voltage at the TP1 test point.
11. With pin 4 and 8 shorted, alternately apply 10 Vdc and -10Vdc between the shorted inputs and GND. Adjust R60 for minimum output.

4.2 TC Zero Adjustment

Verification of the reference junction temperature compensation signal requires a thermometer to measure the ambient temperature next to the transistor Q1. If an external sensor is to be used, the temperature at the sensor location must be measured. Table 6 gives the value of the signal at test point TP1 for ambient temperature ranging from 64° to 88°F.

In addition to correctly positioning the jumpers E4 and E5 in accord with Table 4, the jumpers E2 and E3 must be appropriately placed to use either the local or the remote temperature sensor (see Section II).

After choosing the position for E2 - E5, operate the TC453 for a few minutes to obtain stable warmed-up conditions. No connections to the point 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 6 corresponding to the measured ambient temperature. If the error observed is in excess of ±3°F, the TC ZERO potentiometer, R59, may be adjusted to provide the correct readings.

4.3 Field Servicing Hints

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

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 in that section of this manual.