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T-71-11-07  
**Isolated, Thermocouple  
 Signal Conditioner**

**2B50**

**FEATURES**

Accepts J, K, T, E, R, S or B Thermocouple Types  
 Internally Provided Cold Junction Compensation  
 High CMV Isolation:  $\pm 1500\text{V pk}$   
 High CMR: 160dB min @ 60Hz  
 Low Drift:  $\pm 1\mu\text{V}/^\circ\text{C max}$  (2B50B)  
 High Linearity:  $\pm 0.01\%$  max (2B50B)  
 Input Protection and Filtering  
 Screw Terminal Input Connections

**APPLICATIONS**

Precision Thermocouple Signal Conditioning For:  
 Process Control and Monitoring  
 Industrial Automation  
 Energy Management  
 Data Acquisition Systems

**GENERAL DESCRIPTION**

The model 2B50 is a high performance thermocouple signal conditioner providing input protection, isolation and common mode rejection, amplification, filtering and integral cold junction compensation in a single, compact package.

The 2B50 has been designed to condition low level analog signals, such as those produced by thermocouples, in the presence of high common mode voltages. Featuring direct thermocouple connection via screw terminals and internally provided reference junction temperature sensor, the 2B50 may be jumper programmed to provide cold junction compensation for thermocouple types J, K, T, and B, or resistor programmed for types E, R, and S.

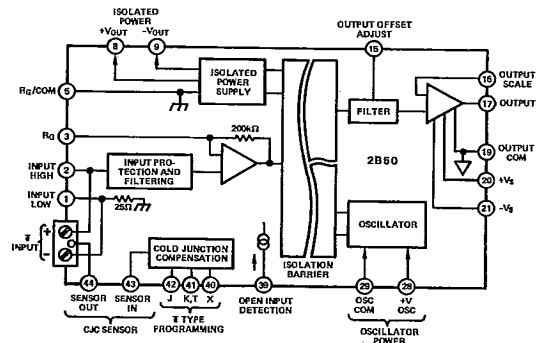
The high performance of the 2B50 is accomplished by the use of reliable transformer isolation techniques. This assures complete input to output galvanic isolation ( $\pm 1500\text{V pk}$ ) and excellent common mode rejection (160dB @ 60Hz).

Other key features include: input protection (220V rms), filtering (NMR of 70dB @ 60Hz), low drift amplification ( $\pm 1\mu\text{V}/^\circ\text{C max}$  - 2B50B), and high linearity ( $\pm 0.01\%$  max - 2B50B).

**APPLICATIONS**

The 2B50 has been designed to provide thermocouple signal conditioning in data acquisition systems, computer interface systems, and temperature measurement and control instrumentation.

**FUNCTIONAL BLOCK DIAGRAM**



In thermocouple temperature measurement applications, outstanding features such as low drift, high noise rejection, and 1500V isolation make the 2B50 an ideal choice for systems used in harsh industrial environments.

**DESIGN FEATURES AND USER BENEFITS**

**High Reliability:** To assure high reliability and provide isolation protection to electronic instrumentation, the 2B50 has been conservatively designed to meet the IEEE Standard for transient voltage protection (472-1974: SWC) and provide 220V rms differential input protection.

**High Noise Rejection:** The 2B50 features internal filtering circuitry for elimination of errors caused by RFI/EMI, series mode noise, and 50Hz/60Hz pickup.

**Ease of Use:** Internal compensation enables the 2B50 to be used with seven different thermocouple types. Unique circuitry offers a choice of internal or remote reference junction temperature sensing. Thermocouple connections may be made either by screw terminals or, in applications requiring PC Board connections, by terminal pins.

**Small Package:** 1.5" X 2.5" X 0.6" size conserves board space.

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# 2B50—SPECIFICATIONS (typical @ +25°C and $V_S = +15V$ unless otherwise noted)

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MODEL	2B50A	2B50B
<b>INPUT SPECIFICATIONS</b>		
Thermocouple Types	J, K, T, or B	*
Jumper Configurable Compensation	R, S, or E	*
Resistor Configurable Compensation		*
Input Span Range	$\pm 5mV$ to $\pm 100mV$	*
Gain Range	$50V/V$ to $1000V/V$	*
Gain Equation	$1 + (200k\Omega/R_G)$	*
Gain Error	$\pm 0.25\%$	*
Gain Temperature Coefficient	$\pm 35ppm/^{\circ}C$ max	$\pm 25ppm/^{\circ}C$ max
Gain Nonlinearity <sup>1</sup>	$\pm 0.025\%$ max	$\pm 0.01\%$ max
Offset Voltage		*
Input Offset (Adjustable to Zero)	$\pm 50\mu V$	*
vs. Temperature	$\pm 2.5\mu V/^{\circ}C$ max	$\pm 1\mu V/^{\circ}C$ max
vs. Time	$\pm 1.5\mu V$ /month	*
Output Offset (Adjustable to Zero)	$\pm 10mV$	*
vs. Temperature	$\pm 30\mu V/^{\circ}C$	*
Total Offset Drift	$\pm (2.5 + \frac{30}{G}) \mu V/^{\circ}C$	$\pm (1 + \frac{30}{G}) \mu V/^{\circ}C$
Input Noise Voltage		*
0.01Hz to 100Hz, $R_S = 1k\Omega$	$1\mu V$ p-p	*
Maximum Safe Differential Input Voltage	220V rms, Continuous	*
CMV, Input to Output		*
Continuous, ac or dc	$\pm 1500V$ pk max	*
Common Mode Rejection		*
@ 60Hz, $1k\Omega$ Source Unbalance	160dB min	*
Normal Mode Rejection @ 60Hz	70dB min	*
Bandwidth	dc to 2.5Hz (-3dB)	*
Input Impedance	100M $\Omega$	*
Input Bias Current <sup>2</sup>	$\pm 5nA$	*
Open Input Detection	Downscale	*
Response Time <sup>3</sup> , $G = 250$	1.4sec	*
Cold Junction Compensation		*
Initial Accuracy <sup>4</sup>	$\pm 0.5^{\circ}C$	*
vs. Temperature <sup>5</sup> ( $+5^{\circ}C$ to $+45^{\circ}C$ )	$\pm 0.01^{\circ}C/^{\circ}C$	*

<b>OUTPUT SPECIFICATIONS</b>		
Output Voltage Range <sup>6</sup>	$\pm 5V$ @ $\pm 2mA$	*
Output Resistance	0.1 $\Omega$	*
Output Protection	Continuous Short to Ground	*

POWER SUPPLY		
Voltage		
Output $\pm V_S$ (Rated Performance)	$\pm 15V$ dc $\pm 10\%$ @ $\pm 0.5mA$	*
(Operating)	$\pm 12V$ to $\pm 18V$ dc max	*
Oscillator $+V_{OSC}$ (Rated Performance)	$+13V$ to $+18V$ @ $15mA$	*

ENVIRONMENTAL		
Temperature Range, Rated Performance		
Operating	0 to $+70^{\circ}C$	*
	$-25^{\circ}C$ to $+85^{\circ}C$	*
Storage Temperature Range	$-55^{\circ}C$ to $+85^{\circ}C$	*
RFI Effect (5W @ 470MHz @ 3ft)		
Error	$\pm 0.5\%$ of Span	*

PHYSICAL		
Case Size	1.5" X 2.5" X 0.6"	*

**NOTES**

\*Specifications same as 2B50A.

<sup>1</sup> Gain nonlinearity is specified as a percentage of output signal span representing peak deviation from the best straight line; e.g., nonlinearity at an output span of 10V pk-pk ( $\pm 5V$ ) is  $\pm 0.01\%$  or  $\pm 1mV$ .

<sup>2</sup> Does not include open circuit detection current of 20mA (optional by jumper connection).

<sup>3</sup> Open input response time is dependent upon gain.

<sup>4</sup> When used with internally provided CJC sensor.

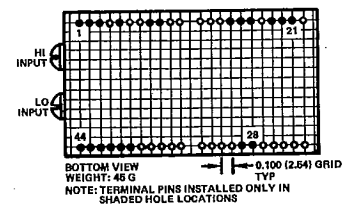
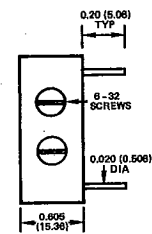
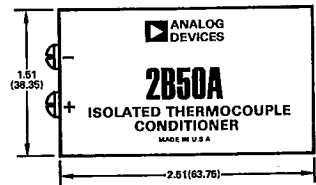
<sup>5</sup> Compensation error contributed by ambient temperature changes at the module.

<sup>6</sup> Output swing of  $\pm 10V$  may be obtained through output scaling (Figure 5).

Specifications subject to change without notice.

## OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



### PIN DESIGNATIONS

PIN	FUNCTION	PIN	FUNCTION
1	INPUT LO	23	
2	INPUT HI	24	
3	$R_a$	25	
4		26	
5	$R_a/COM$	27	
6		28	$+V_{OSC}$
7		29	$OSC/COM$
8	$+V$ ISO OUT	30	
9	$-V$ ISO OUT	31	
10		32	
11		33	
12		34	
13		35	
14		36	
15	OUTPUT OFFSET ADJUST	37	
16	OUTPUT SCALE	38	OPEN INPUT DET.
17	OUTPUT	40	X TYPE PROGRAMMING
18		41	K, T
19		42	J
20	OUTPUT COM	43	CJC SENSOR IN
21	$+V_S$	44	CJC SENSOR OUT
22	$-V_S$		

**MATING SOCKET:**  
AC1218

**FUNCTIONAL DESCRIPTION**

The internal structure of the 2B50 is shown in Figure 1. An input filtering and protection network precedes a low drift, high performance amplifier whose gain is set by a user supplied resistor ( $R_G$ ) for gains of 50 to 1000V/V. Isolated power is brought out to permit convenient adjustment of the input offset voltage, if desired.

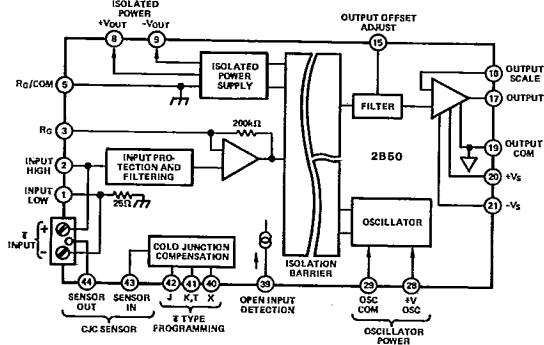


Figure 1. 2B50 Functional Block Diagram

Internal circuitry provides reference junction compensation. An integral reference junction sensor is provided for direct thermocouple connections, or an external reference sensor (2N2222 transistor) may be used in applications having remote thermocouple termination. Compensating networks for thermocouple types J, K, and T are built into the 2B50. A fourth compensation (X) may be programmed with a single resistor for any other thermocouple type. The 2B50 can be programmed for uncompensated output when used with inputs other than thermocouples.

Transformer coupling is used to achieve stable, reliable input to output galvanic isolation, as well as elimination of ground loop error effects.

Normally, the full scale output of the 2B50 is  $\pm 5V$ . However, with the addition of an external resistive divider, the output buffer amplifier may be scaled for a gain of up to 2, providing a full scale output swing of  $\pm 10V$ .

**OPERATING INSTRUCTIONS**

The connections shown in Figure 2 are common to most applications using the 2B50, and, in many cases, will be all that is required.

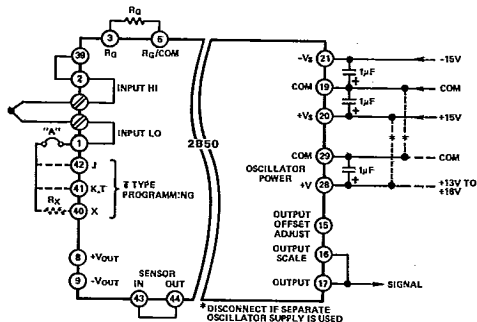


Figure 2. Basic 2B50 Application

REV. A

Two sets of parallel thermocouple input connections are provided. The thermocouple input may be connected by screw terminals (Input+, Input-) or to terminal Pins 1(-) and 2(+) in cases where thermocouples are to be remotely terminated. The following sections describe a basic thermocouple application, as well as detail some optional connections to enhance performance in more demanding applications. Jumper A (Figure 2) is used to disconnect cold junction compensation circuitry during offset adjustments.

**INTERCONNECTION GUIDELINES**

All power supply inputs should be decoupled with  $1\mu F$  capacitors as close to the unit as possible. Any jumpers installed for programming purposes should also be installed as close as possible to minimize noise pickup effects.

Since the oscillator section of the 2B50 accounts for most of the power consumption but can accept a wide range of voltage (+13V to +18V), it may be desirable to power this section from a convenient source of unregulated power.

If the same supply is to be used for both amplifier and oscillator circuitry, the power supply returns should be brought out separately so that oscillator power supply currents do not flow in the low lead of the signal output. In either case, a  $1\mu F$  capacitor must be connected from +V<sub>OSC</sub> (Pin 28 to Oscillator COM (Pin 29).

The oscillator and amplifier sections are completely isolated; therefore, a dc power return path is not required between the two power supply commons.

**GAIN SETTING**

The gain of the 2B50 is set by a user-supplied resistor ( $R_G$ ) connected as shown in Figure 2. Gain will normally be selected so that the maximum output of the signal source will result in a plus full scale output swing. The resistor value required is determined by the equation:  $R_G = 200k\Omega/G-1$ .

A series trim on the gain setting resistor can be used to trim out the resistor tolerance and module gain error (Figure 3). Since addition of a series resistance will always decrease gain, the value of the gain-setting resistor should be selected to provide a gain somewhat higher than the desired trimmed gain. A good quality (e.g., 10ppm/ $^{\circ}C$ ), metal-film resistor should be used for  $R_G$ , since drift of  $R_G$  will add to the overall gain drift of the 2B50. A cermet pot is suitable for the trim. Note that a minimum gain of 50 is required for guaranteed operation.

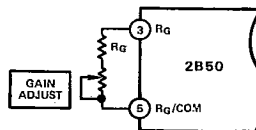


Figure 3. Gain Adjustment

**INPUT AND OUTPUT OFFSET ADJUSTMENTS**

The 2B50 has provisions for adjusting input and output offset errors of the module. None of the offset adjustments will affect drift performance, and adjustments need not be used unless the particular application calls for lower offsets than those specified.

Connections for offset adjustments are shown in Figure 4. Isolated supply voltages are brought out for input trimming convenience only and are not for use as a power supply for external components.

## 2B50

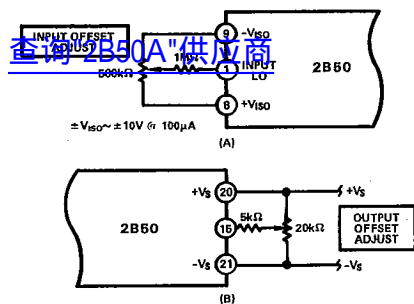


Figure 4. (A) Input and (B) Output Offset Adjustment

## OFFSET CALIBRATION

1. Short Input + and Input - together.
2. Disconnect cold junction compensation circuitry by removing Jumper "A" (Figure 2).
3. Adjust input offset trim pot ( $\pm 250\mu\text{V}$  range, RT1) to zero output while operating at the desired gain. In most applications, adjustment of the input offset alone will be sufficient. Output offset adjustment ( $\pm 30\text{mV}$  range) may be performed if it is desired to adjust output offset on the nonisolated side.

## OPEN INPUT DETECTION

Connecting the open input detection pin (Pin 39) to Input High (Pin 2) creates a 20nA bias current which will provide a negative overscale response if the input is opened, or in case of thermocouple "burn out". The speed at which this occurs is dependent on gain, with a typical response time of 1.4sec @  $G = 250$ . For positive upscale response, connect a 500M $\Omega$  resistor between  $+V_{ISO}$  (Pin 8) and Input Hi (Pin 2).

## OUTPUT SCALING

With the output scale (Pin 16) connected to the output (Pin 17), the full scale output range is  $\pm 5\text{V}$  and the total gain is equal to the gain set by  $R_G$ . For applications requiring a full scale output of  $\pm 10\text{V}$ , a resistive divider may be connected to provide a gain of 2 at the output amplifier (see Figure 5). In this configuration, total gain will be twice the gain set by  $R_G$ . Output gains greater than 2 cannot be used.

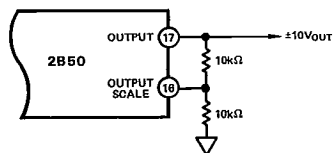


Figure 5. Output Scaling Connections

## COLD JUNCTION COMPENSATION

The 2B50 may be programmed to provide cold junction compensation for types J, K and T thermocouples by connecting a jumper from Input Low (Pin 1) to the appropriate programming points (Pin 42 for J, Pin 41 for K or T). To compensate other thermocouple types, a resistor ( $R_X$ ) is connected from the "X" programming point (Pin 40) to Input Low (Pin 1). Table I shows the appropriate  $R_X$  values for types E, R, and S.  $R_X$  should be a 50ppm/ $^{\circ}\text{C}$ , 1% tolerance resistor.

Type B thermocouples are unique, in that they have almost no output in the  $+5^{\circ}\text{C}$  to  $+45^{\circ}\text{C}$  range, and therefore, do not require cold junction compensation at all. To accommodate a type B thermocouple, resistor  $R_X$  must be left open. Error due to cold junction temperature will be less than  $\pm 1^{\circ}\text{C}$  for any measurement above  $260^{\circ}\text{C}$ . In the measurement range above  $1000^{\circ}\text{C}$  (where type B thermocouples are normally used) the error will be less than  $\pm 0.3^{\circ}\text{C}$ .

TC Type	$R_X$ (k $\Omega$ )
E	1.85
R, S	19.6
B	Open

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Table I. Compensation Values for Thermocouple Types E, R, S and B

## REMOTE REFERENCE SENSING

In applications requiring termination of thermocouple leads at a point located remotely from the 2B50, with connections brought to the 2B50 (Pins 1, 2) by copper wires, reference temperature sensing at the remote location will be necessary. The 2B50 has provisions for connection of a 2N2222 transistor (metal can version) for use as a reference junction sensor. The connections are shown in Figure 6. The remote sensing transistor is calibrated by adjusting  $R_{CAL}$  to obtain the value of  $V_{CAL}$  as specified in Table II.

(Example:  $V_{CAL} = 570.0\text{mV}$  @  $25^{\circ}\text{C}$ )

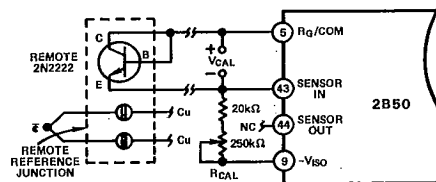


Figure 6. Remote Reference Junction Sensing

Sensor Temp ( $^{\circ}\text{C}$ )	$V_{CAL}$ (mV)
5	616.5
10	604.9
15	593.3
20	581.6
25	570.0
30	558.4
35	546.8
40	535.1
45	523.5

(Values may be interpolated)

Table II. Calibration Voltages vs. Sensor Temperature

Proper sensor placement is important. Close thermal contact of the sensor and thermocouple termination point (reference junction) is essential for accurate operation of the 2B50. The sensor may be placed any distance from the 2B50. When the sensor leads are more than ten feet long, or in the presence of strong noise signal sources, shielded cable should be used.