

# Thermocouple Cold Junction Compensator and Matched Amplifier

## FEATURES

- 0.75°C Initial Accuracy (A Version)
- Extremely Low Warmup Drift
- Preset Outputs for Type E, J, K, R, S, T
- Single 5V to ±20V Operation
- 480μA Typical Supply Current

## APPLICATIONS

- Thermocouple Cold Junction Compensation

## DESCRIPTION

The LTK001 is a thermocouple amplifier supplied with a matched cold junction compensator. By separating the amplifier and compensator functions, the problem of compensator temperature rise is virtually eliminated. The compensator is a selected version of the LT1025 cold junction compensator. The amplifier, which is also available separately as LTKA0x has been specially selected for thermocouple applications. It has low supply current to minimize warmup drift, very low offset voltage (<35μV), high gain,

and extremely low input bias currents (<600pA) to allow high impedance input filters to be used without degrading offset voltage or drift.

Matching of the kits is accomplished by separating the compensators and amplifiers according to the polarity of their initial (room temperature) errors. This eliminates the need to sum the errors of the two components to find the worst-case error.

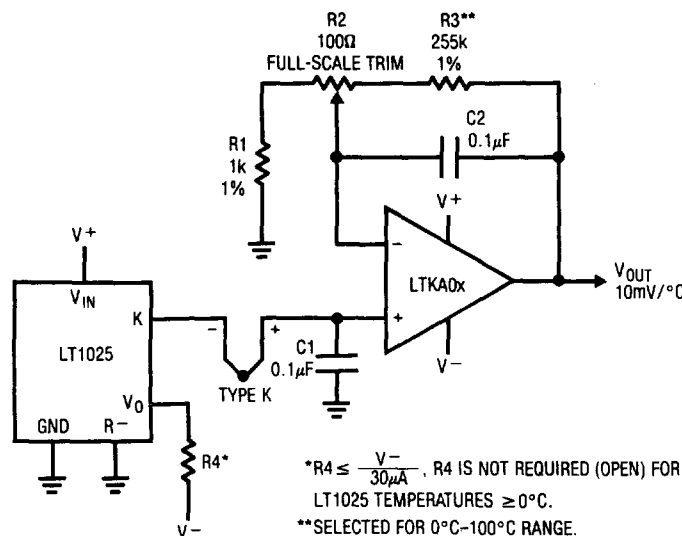
The LTK001 has direct thermocouple outputs of 60.9μV/°C (E), 51.7μV/°C (J), 40.6μV/°C (K, T), and 5.95μV/°C (R, S). It also has a 10mV/°C output which can be scaled to match any arbitrary thermocouple.

The amplifier in the LTK001 kit is available in an 8-pin plastic miniDIP for 0°C to 70°C operation and an 8-pin TO-39 metal can for -55°C to +125°C operation. The compensator is available in 8-pin plastic miniDIP for 0°C to 70°C operation and 8-pin ceramic miniDIP for -55°C to +125°C operation.

For multiple thermocouple applications using one compensator, amplifiers may be ordered separately (LTKA0x), still matched to the compensator.

For typical performance curves and applications circuits consult the LT1025 data sheet.

Type K 10mV/°C Thermometer



**ABSOLUTE MAXIMUM RATINGS**

**Amplifier (LTKA0x)**

Supply Voltage (Total  $V^+$  to  $V^-$ ) ..... 40V  
 Differential Input Current (Note 1).....  $\pm 10\text{mA}$   
 Common-Mode Input Voltage ..... Equal to Supplies  
 Output Short Circuit Duration ..... Indefinite

**Compensator (LT1025)**

Supply Voltage ( $V_{IN}$  to Ground Pin) ..... 36V  
 Output Voltage (Forced) ..... 5V  
 Output Short Circuit Duration ..... Indefinite

**Both Devices**

Operating Temperature Range  
 LTK001AMJ, LTK001MJ .....  $-55^\circ\text{C}$  to  $125^\circ\text{C}$   
 LTK001ACN, LTK001CN .....  $0^\circ\text{C}$  to  $70^\circ\text{C}$   
 Storage Temperature Range .....  $-65^\circ\text{C}$  to  $150^\circ\text{C}$   
 Lead Temperature Range (Soldering, 10 sec.) .....  $300^\circ\text{C}$

**PACKAGE/ORDER INFORMATION**

<p>TOP VIEW</p> <p>Plastic DIP COMPENSATOR (LT1025):              1: <math>60.9\mu\text{V}/^\circ\text{C}</math> (E)              2: <math>V_{IN}</math>              3: <math>10\text{mV}/^\circ\text{C}</math> (<math>V_O</math>)              4: GND</p> <p>Hermetic DIP COMPENSATOR (LT1025):              5: R- COMMON              6: R,S <math>6\mu\text{V}/^\circ\text{C}</math>              7: K,T <math>40.6\mu\text{V}/^\circ\text{C}</math>              8: J <math>51.7\mu\text{V}/^\circ\text{C}</math></p>	<p>ORDER PART NUMBER</p> <p><b>KIT</b>                  LTK001CN                  LTK001ACN                  LTK001MJ                  LTK001AMJ</p>
<p>TOP VIEW</p> <p>Plastic DIP AMPLIFIER (LTKA0x):              1: <math>V_{OS}</math> TRIM              2: -IN              3: +IN              4: <math>V^-</math>              5: OVER COMP              6: OUT              7: <math>V^+</math>              8: <math>V_{OS}</math> TRIM</p>	<p><b>AMPLIFIER ONLY (Note A)</b>                  LTKA00CN8                  LTKA01CN8</p>
<p>TOP VIEW</p> <p>Metal Can AMPLIFIER (LTKA0x):              1: <math>V_{OS}</math> TRIM              2: -IN              3: +IN              4: <math>V^-</math>              5: OVER-COMP              6: OUT              7: <math>V^+</math>              8: <math>V_{OS}</math> TRIM</p>	<p><b>AMPLIFIER ONLY (Note A)</b>                  LTKA00MH                  LTKA01MH</p>

**Note A:** The polarity of the amplifier is indicated by the 0 or 1 in the part number. An LT1025 with a 0 identifier is properly matched with an LTKA00 while an LT1025 with a 1 identifier should be used with an LTKA01.

**ELECTRICAL CHARACTERISTICS — MATCHED AMPLIFIER AND COMPENSATOR**  $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$  (Amplifier),  $V_S = 5\text{V}$  (Compensator)

PARAMETER	CONDITIONS	LTK001A			LTK001			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Total Temperature Error @25°C (Note 2)		Type E			0.75		2.5	$^\circ\text{C}$
		Type J			0.75		2.5	$^\circ\text{C}$
		Type K, T			0.86		2.5	$^\circ\text{C}$
		Type R, S	(Note 11)		5.0		5.0	$^\circ\text{C}$
Slope Error (Notes 3 and 8)	$0^\circ\text{C} \leq T_j \leq 70^\circ\text{C}$	Type E			0.05		0.09	$^\circ\text{C}/^\circ\text{C}$
		Type J			0.06		0.09	$^\circ\text{C}/^\circ\text{C}$
		Type K, T			0.07		0.10	$^\circ\text{C}/^\circ\text{C}$
		Type R, S			0.28		0.32	$^\circ\text{C}/^\circ\text{C}$
Total Temperature Error at Temperature Extremes (Note 8)	$0^\circ\text{C} \leq T_j \leq 70^\circ\text{C}$	Type E			2.0		5	$^\circ\text{C}$
		Type J			2.1		5	$^\circ\text{C}$
		Type K, T			2.6		5.2	$^\circ\text{C}$
		Type R, S	(Note 11)		16		16	$^\circ\text{C}$
	$-55^\circ\text{C} \leq T_j \leq 125^\circ\text{C}$	Type E			6		8.5	$^\circ\text{C}$
		Type J			6		8.5	$^\circ\text{C}$
		Type K, T			6.3		9	$^\circ\text{C}$
		Type R, S	(Note 11)		30		30	$^\circ\text{C}$
Temperature Error Change with Supply Voltage (Note 4)				0.1		0.1	$^\circ\text{C}/\text{V}$	
Supply Current				480	900	480	900	$\mu\text{A}$

## ELECTRICAL CHARACTERISTICS COMPENSATOR (LT1025) $V_S = 5V$ unless otherwise specified

PARAMETER	CONDITIONS		COMPENSATOR (LT1025)			UNITS
			MIN	TYP	MAX	
Temperature Error at 10mV/°C Output (Note 8)	$T_j = 25^\circ\text{C}$	LTK001A		0.3	0.5	°C
		LTK001		0.5	2.0	°C
	Full Temperature Span	●	See Curve on LT1025 Data Sheet			
Temperature Error at Individual Outputs (Note 9)	LTK001A	E, J, K, T		0.4	0.75	°C
		R, S		0.4	1.5	°C
	LTK001	E, J, K, T		0.8	2.4	°C
		R, S		1.2	3.5	°C
	Full Temperature Span	●	See Curve on LT1025 Data Sheet			
Supply Current	$4V \leq V_{IN} \leq 36V$			80	100	$\mu\text{A}$
	$0^\circ\text{C} \leq T_j \leq 70^\circ\text{C}$		●		150	$\mu\text{A}$
	$-55^\circ\text{C} \leq T_j \leq 125^\circ\text{C}$		●		200	$\mu\text{A}$
Change in Supply Current	$4V \leq V_{IN} \leq 36V$			0.01	0.05	$\mu\text{A/V}$
Line Regulation (Note 10)	$4V \leq V_{IN} \leq 36V$ 10mV/°C Output		●	0.003	0.02	°C/V
Load Regulation (Note 10)	$0 \leq I_O \leq 1\text{mA}$ 10mV/°C Output		●	0.04	0.2	°C
Divider Impedance		E		2.5		k $\Omega$
		J		2.1		k $\Omega$
		K, T		4.4		k $\Omega$
		R, S		3.8		k $\Omega$

## ELECTRICAL CHARACTERISTICS AMPLIFIER (LTKA0x) $V_S = \pm 15V$ , $V_{CM} = 0$ , $T_j = 25^\circ\text{C}$ , unless otherwise specified

PARAMETER	CONDITIONS		AMPLIFIER (LTKA0x)			UNITS
			MIN	TYP	MAX	
Input Offset Voltage				10	35	$\mu\text{V}$
Input Offset Voltage Drift with Temperature	(Note 5)	●		0.3	1.5	$\mu\text{V}/^\circ\text{C}$
Input Bias Current	$0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ $-55^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$	●		$\pm 200$	$\pm 600$	pA
		●		$\pm 300$	$\pm 1500$	pA
Input Bias Current Drift with Temperature	(Note 5)	●		1	5	$\text{pA}/^\circ\text{C}$
Input Offset Current	$0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ $-55^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$	●		$\pm 100$	$\pm 500$	pA
		●		$\pm 200$	$\pm 700$	pA
Input Offset Current Drift with Temperature	(Note 5)	●		0.6	4	$\text{pA}/^\circ\text{C}$
Large Signal Voltage Gain	$R_L = 10\text{k}\Omega$	●	400	2000		V/mV
Common-Mode Rejection Ratio	$V_{CM} = \pm 13.5V$	●	106	130		dB
Power Supply Rejection Ratio	$\pm 2.5V \leq V_S \leq \pm 20V$ (Note 4)	●	106	125		dB
Common-Mode Input Voltage Range	Notes 5 and 6	Above $V^-$		0.75		V
		Below $V^+$			1.0	V
Output Voltage Swing (Notes 5 and 7)	Referred to Supplies	$I_{OUT} = 0.1\text{mA}$		0.8		V
		$I_{OUT} = 1\text{mA}$		1.1		V
Supply Current		●		400	800	$\mu\text{A}$
Supply Voltage Range	Total $V^+$ to $V^-$ Voltage	●	4.5		40	V

The ● denotes the specifications which apply over the full operating temperature range.

**Note 1:** The inputs of the LTKA0x amplifier are clamped with diodes, so a differential voltage rating does not apply.

**Note 2:** Total temperature error is the overall error at 25°C taking into account the offset of the amplifier, the offset at the compensator 10mV/°C output, and the error in the compensator divider network. Warmup drift is not included.

**Note 3:** Slope error is the increase in total temperature error as ambient temperature is increased. It is guaranteed by design and by other tests, but is not tested directly.

**Note 4:** This is a worst-case limit assuming that any or all supply voltages change.

**Note 5:** Guaranteed, but not tested.

**Note 6:** By referring common-mode range to the supplies, the range referred to ground can be quickly calculated for any given supply voltage. With a single 5V supply, for instance, which has a worst-case low value of 4.7V, the upper common-mode limit is 4.7V - 1V = 3.7V. The lower common-mode limit is 0V + 0.75V = 0.75V. With ± 15V supplies, the limits would be + 14V and - 14.25V, respectively. Common-mode range has a temperature sensitivity of ≈ 2mV/°C.

**Note 7:** Absolute output voltage swing is calculated by subtracting the

given limits from actual supply voltage. These limits indicate the point where offset voltage has changed suddenly by 5μV.

**Note 8:** Temperature error is defined as the deviation from the following formula:

$$V_{OUT} = \alpha(T) + \alpha\beta(T - 25^\circ\text{C})^2$$

$\alpha$  = Typical thermocouple Seebeck coefficient as follows, E = 60.9μV/°C, J = 51.7μV/°C, K, T = 40.6μV/°C, R, S = 5.95μV/°C.  $\alpha$  = 10mV/°C at the 10mV output.

$\beta$  = Nonlinearity coefficient built into the LT1025 to help compensate for the nonlinearities of thermocouples.  $\beta = 5.5 \times 10^{-4}$ , generating 0.34°C bow for 25°C temperature change, and 1.36°C bow for 50°C change.

**Note 9:** Temperature error at the individual outputs is the sum of the 10mV/°C output error plus the resistor divider error.

**Note 10:** Line and load regulation do not take into account the effects of self-heating. Output changes due to self-heating can be calculated as follows:

$$\Delta V_{OUT} (\text{Line}) = \Delta V_{IN} (I_q + I_{load}) (150^\circ\text{C/W})$$

$$\Delta V_{OUT} (\text{Load}) = (\Delta I_{load}) (V_{IN}) (150^\circ\text{C/W})$$

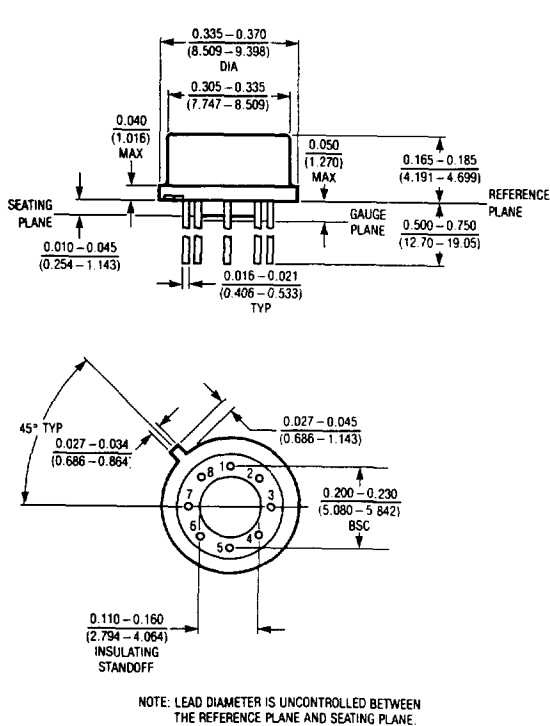
$$I_q = \text{LT1025 supply current}$$

Load regulation is 30μA ≤ I<sub>O</sub> ≤ 1mA for T<sub>A</sub> ≤ 0°C.

**Note 11:** Larger errors with type R and S thermocouples are due mostly to 35μV offset of the amplifier. This error can be reduced to 5μV max with the LTC1050 or LTC1052 operational amplifiers.

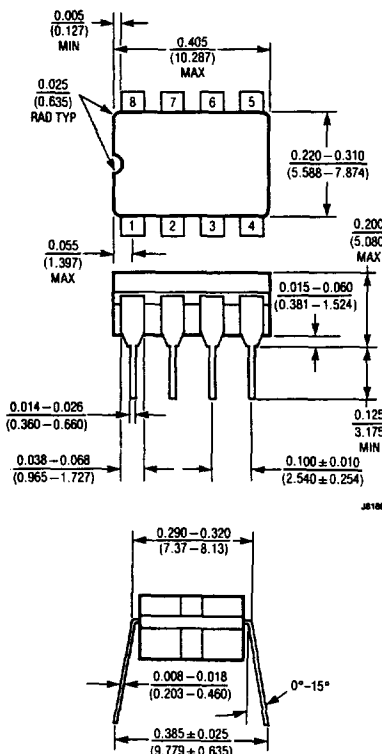
## PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

**H Package**  
8 Lead TO-5 Metal Can



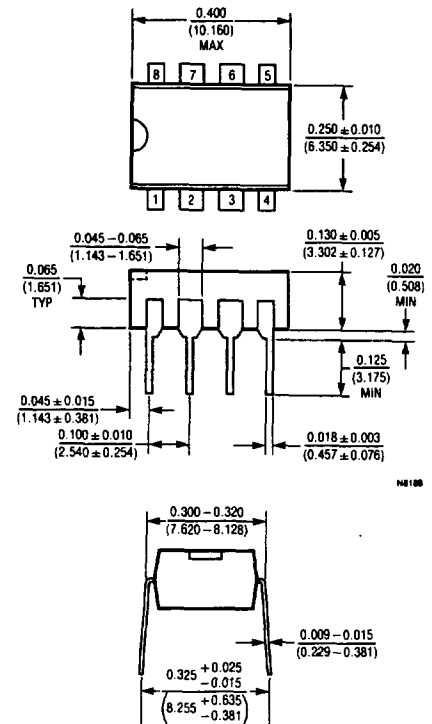
T <sub>J</sub> MAX	θ <sub>JA</sub>	θ <sub>JC</sub>
150°C	150°C/W	45°C/W

**J Package**  
8 Lead Hermetic DIP



T <sub>J</sub> MAX	θ <sub>JA</sub>
150°C	100°C/W

**N Package**  
8 Lead Molded DIP



T <sub>J</sub> MAX	θ <sub>JA</sub>
100°C	130°C/W