

Micropower Precision Series Reference


September 1996

FEATURES

- Trimmed to High Accuracy: **0.075% Max**
- Low Drift: **10ppm/°C Max**
- **No Output Capacitor Required**
- Low Supply Current: 130µA Max
- Minimum Output Current: 20mA
- Industrial Temperature Range SO Package
- Reverse Battery Protection
- Minimum Input/Output Differential: 0.9V

APPLICATIONS

- Handheld Instruments
- Precision Regulators
- A/D and D/A Converters
- Power Supplies
- Hard Disk Drives

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DESCRIPTION

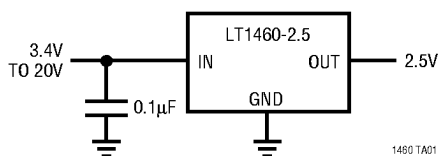
The LT[®]1460 is a micropower bandgap reference that combines very high accuracy and low drift with low power dissipation and small package size. This series reference uses curvature compensation to obtain low temperature coefficient and trimmed precision thin-film resistors to achieve high output accuracy. The reference will supply up to 20mA, making it ideal for precision regulator applications, and it is almost totally immune to input voltage variations.

This series reference provides supply current and power dissipation advantages over shunt references that must idle the entire load current to operate. Additionally, the LT1460 does not require an output compensation capacitor, but it is stable with capacitive loads. This feature is important in critical applications where PC board space is a premium or fast settling is demanded. Reverse battery protection keeps the reference from conducting current and being damaged.

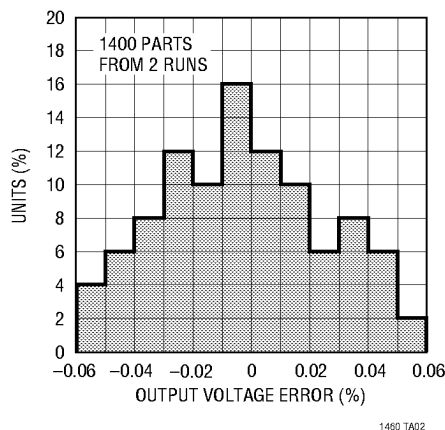
The LT1460 is available in 2.5V, 5V and 10V output voltages and comes in the 8-lead SO and PDIP packages.

TYPICAL APPLICATION

Basic Connection



Typical Distribution of Output Voltage



ABSOLUTE MAXIMUM RATINGS

Input Voltage	25V	Specified Temperature Range	0°C to 70°C
Reverse Voltage	–20V	Storage Temperature Range (Note 1) ...	–65°C to 150°C
Output Short-Circuit Duration, T _A = 25°C		Lead Temperature (Soldering, 10 sec).....	300°C
V _{IN} > 15V	5 sec		
V _{IN} ≤ 15V	Indefinite		

PACKAGE/ORDER INFORMATION

<p>TOP VIEW</p> <p>N8 PACKAGE 8-LEAD PDIP</p> <p>*CONNECTED INTERNALLY. DO NOT CONNECT EXTERNAL CIRCUITRY TO THESE PINS</p> <p>T_{JMAX} = 125°C, θ_{JA} = 130°C/W</p>	<p>ORDER PART NUMBER</p> <p>LT1460ACN8-2.5 LT1460BCN8-2.5</p>	<p>TOP VIEW</p> <p>S8 PACKAGE 8-LEAD PLASTIC SO</p> <p>*CONNECTED INTERNALLY. DO NOT CONNECT EXTERNAL CIRCUITRY TO THESE PINS</p> <p>T_{JMAX} = 125°C, θ_{JA} = 190°C/W</p>	<p>ORDER PART NUMBER</p> <p>LT1460ACS8-2.5 LT1460BCS8-2.5</p> <p>S8 PART MARKING</p> <p>1460A2 1460B2</p>
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Consult factory for Industrial grade parts.

ELECTRICAL CHARACTERISTICS V_{IN} = V_{OUT} + 2.5V, I_{OUT} = 0, T_A = 25°C unless otherwise specified.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage (Note 2)	LT1460A-2.5		2.498125 –0.075	2.500 0.02	2.501875 0.075	V %
	LT1460B-2.5		2.4975 –0.1	2.500 0.05	2.5025 0.10	V %
Output Voltage Temperature Coefficient (Note 3)	T _{MIN} ≤ T _J ≤ T _{MAX} LT1460A			5	10	ppm/°C
	LT1460B			10	20	ppm/°C
Line Regulation	(V _{OUT} + 0.9V) ≤ V _{IN} ≤ (V _{OUT} + 2.5V)	●		30	60 80	ppm/V ppm/V
	(V _{OUT} + 2.5V) ≤ V _{IN} ≤ 20V	●		10	25 35	ppm/V ppm/V
Load Regulation (Note 4) Sourcing	I _{OUT} = 100μA	●		1500	2800 3500	ppm/mA ppm/mA
	I _{OUT} = 10mA	●		80	135 180	ppm/mA ppm/mA
	I _{OUT} = 20mA 0°C ≤ T _A ≤ 70°C	●		70	100 140	ppm/mA ppm/mA
Dropout Voltage (Note 5)	V _{IN} – V _{OUT} , I _{OUT} = 0, ΔV _O ≤ 0.1%	●			0.9	V
	V _{IN} – V _{OUT} , I _{OUT} = 10mA, ΔV _O ≤ 0.1%	●			1.3	V
	V _{IN} – V _{OUT} , I _{OUT} = 10mA, ΔV _O ≤ 0.1%	●			1.4	V

ELECTRICAL CHARACTERISTICS

 $V_{IN} = V_{OUT} + 2.5V$, $I_{OUT} = 0$, $T_A = 25^\circ C$ unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Current	Short V_{OUT} to GND	25	40		mA
Reverse Leakage	$V_{IN} = -20V$	●	0.5	10	μA
Supply Current		●	100	130 165	μA μA
Output Voltage Noise (Note 6)	$0.1Hz \leq f \leq 10Hz$		4		ppm _(P-P)
Hysteresis (Note 7)	$\Delta T = -40^\circ C$ to $85^\circ C$ $\Delta T = 0^\circ C$ to $70^\circ C$		160 25		ppm ppm

The ● denotes specifications which apply over the specified temperature range.

Note 1: If the part is stored outside of the specified temperature range, the output may shift due to hysteresis.

Note 2: ESD (Electrostatic Discharge) sensitive device. Extensive use of ESD protection devices are used internal to the LT1460, however, high electrostatic discharge can damage or degrade the device. Use proper ESD handling precautions.

Note 3: Temperature coefficient is measured by dividing the change in output voltage by the specified temperature range. Incremental slope is also measured at $25^\circ C$.

Note 4: Load regulation is measured on a pulse basis from no load to the specified load current. Output changes due to die temperature change must be taken into account separately.

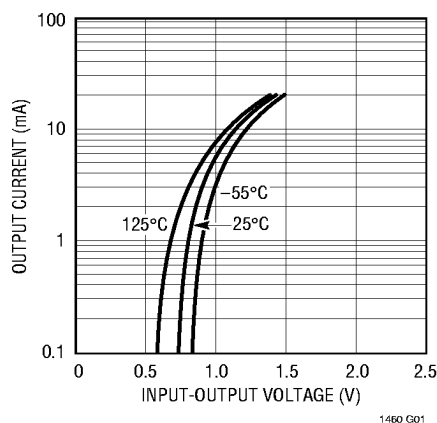
Note 5: Excludes load regulation errors.

Note 6: Peak-to-peak noise is measured with a single highpass filter at 0.1Hz and 2-pole lowpass filter at 10Hz.

Note 7: Hysteresis in output voltage is created by package stress that differs depending on whether the IC was previously at a higher or lower temperature. Output voltage is always measured at $25^\circ C$, but the IC is cycled to $85^\circ C$ or $-40^\circ C$ before successive measurements. Hysteresis is roughly proportional to the square of the temperature change. Hysteresis is not normally a problem for operational temperature excursions where the instrument might be stored at high or low temperature.

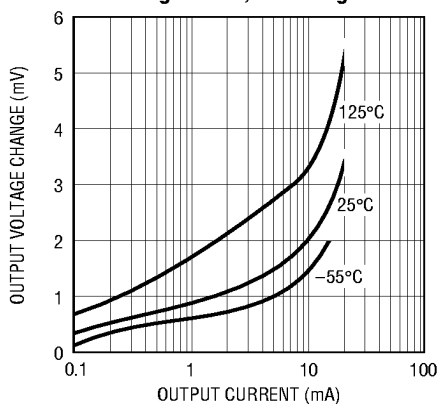
TYPICAL PERFORMANCE CHARACTERISTICS

Minimum Input-Output Voltage Differential



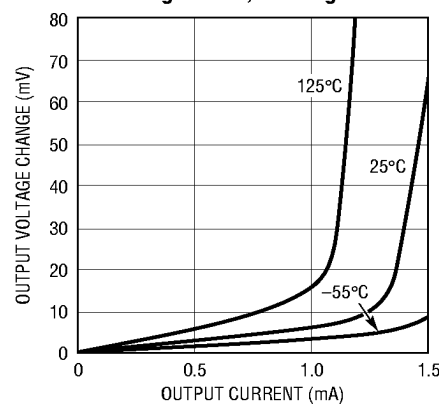
1460 G01

LT1460-2.5 Load Regulation, Sourcing



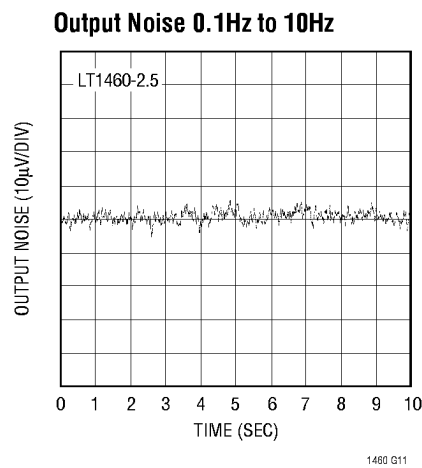
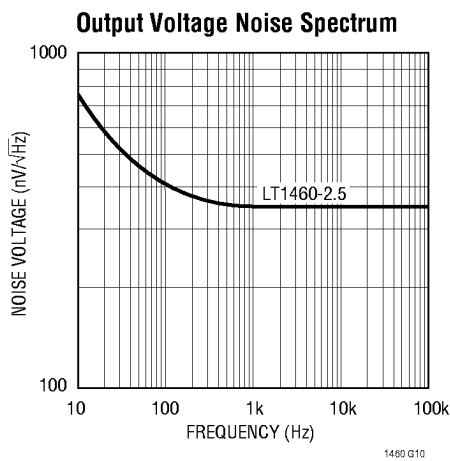
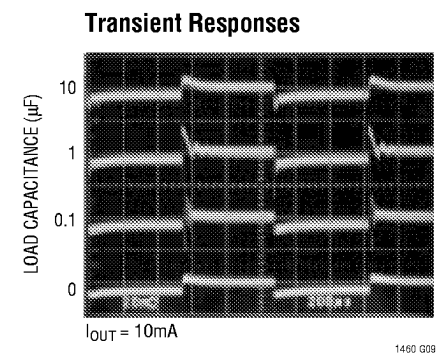
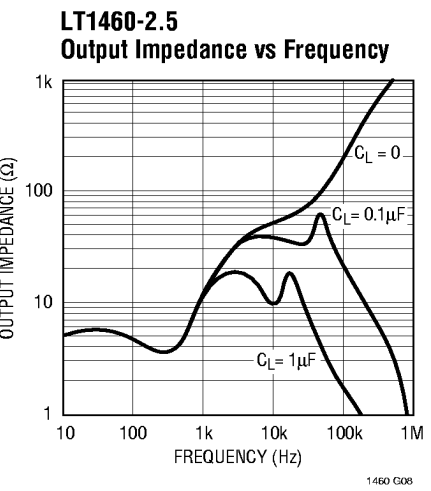
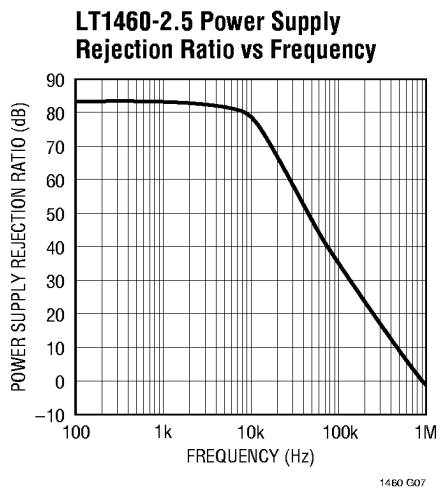
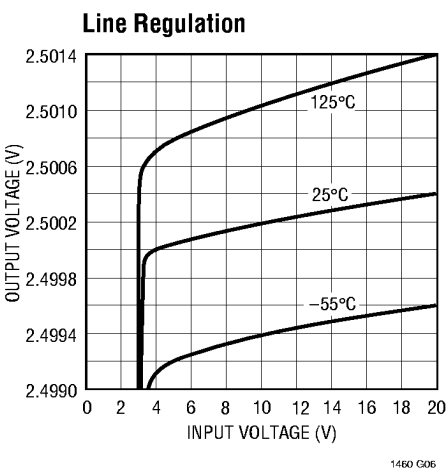
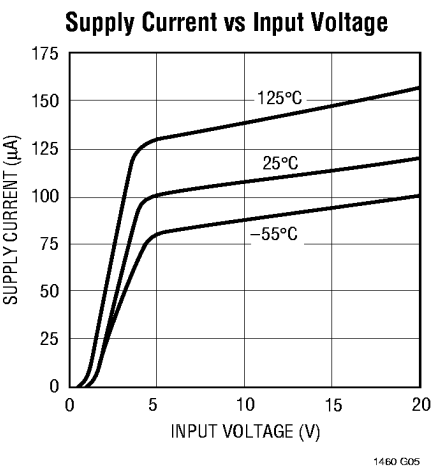
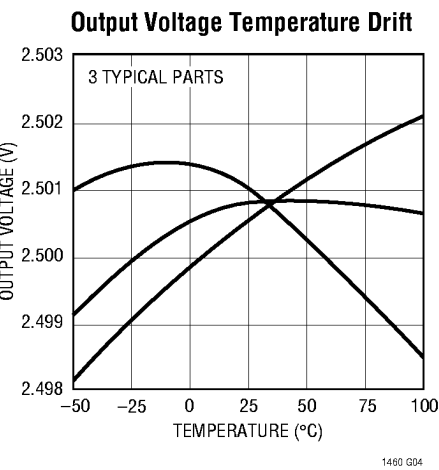
1460 G02

LT1460-2.5 Load Regulation, Sinking



1460 G03

TYPICAL PERFORMANCE CHARACTERISTICS



APPLICATIONS INFORMATION

Longer Battery Life

Series references have a large advantage over older shunt style references. Shunt references require a resistor from the power supply to operate. This resistor must be chosen to supply the maximum current that can ever be demanded by the circuit being regulated. When the circuit being controlled is not operating at this maximum current, the shunt reference must always sink this current, resulting in high dissipation and short battery life.

The LT1460 series reference does not require a current setting resistor and can operate with any supply voltage from $V_{OUT} + 0.9V$ to $20V$. When the circuitry being regulated does not demand current, the LT1460 reduces its dissipation and battery life is extended. If the reference is not delivering load current it dissipates only $500\mu W$ on a $5V$ supply, yet the same connection can deliver $20mA$ of load current when demanded.

Capacitive Loads

The LT1460 is designed to be stable with or without capacitive loads. With no capacitive load, the reference is ideal for fast settling or applications where PC board space is a premium. The test circuit shown in Figure 1 is used to measure the response time for various load currents and load capacitors. The $1V$ step from $2.5V$ to $1.5V$ produces a current step of $1mA$ or $100\mu A$ for $R_L = 1k$ or $R_L = 10k$. Figure 2 shows the response of the reference with no load capacitance. The reference settles to $2.5mV$ (0.1%) in less than $1\mu s$ for a $100\mu A$ pulse and to 0.1% in $1.5\mu s$ with a $1mA$ step.

When load capacitance is greater than $0.01\mu F$, the reference begins to ring due to the pole formed with the output impedance. Figure 3 shows the response of the reference to a $1mA$ and $100\mu A$ load transient with a $0.01\mu F$ load capacitor. The ringing will be greatly reduced with a DC load as small as $200\mu A$. With large output capacitors, $\geq 1\mu F$, the ringing can be reduced with a small resistor in series with the reference output as shown in Figure 4. Figure 5 shows the response of the LT1460 with a $R_S = 2\Omega$ and $C_L = 1\mu F$. R_S should not be made arbitrarily large because it will limit the load regulation.

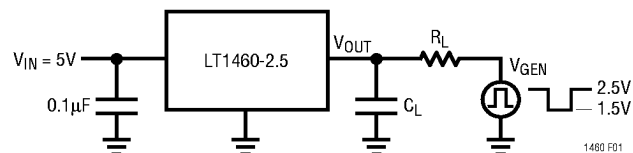


Figure 1. Response Time Test Circuit

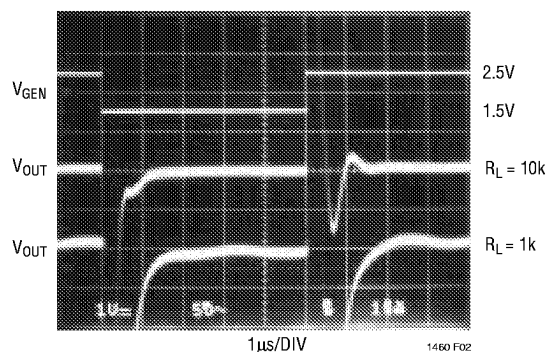


Figure 2. $C_L = 0$

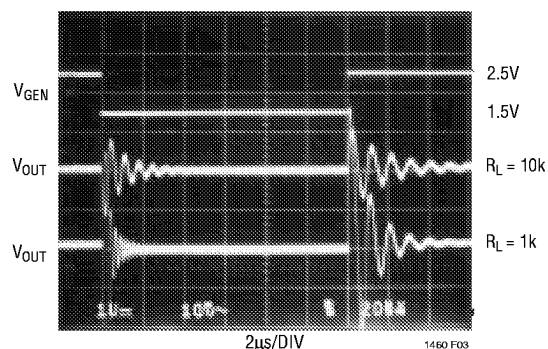


Figure 3. $C_L = 0.01\mu F$

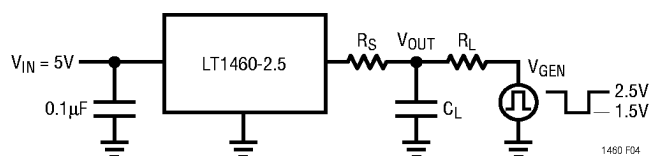
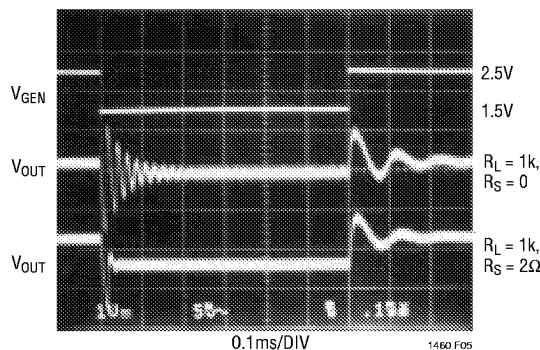
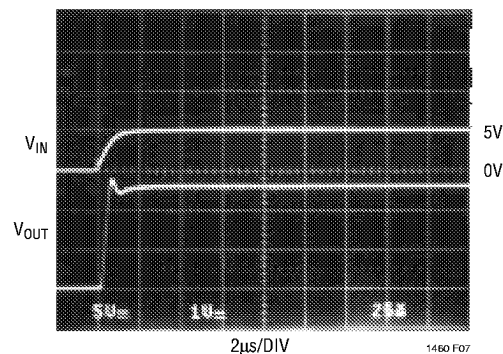


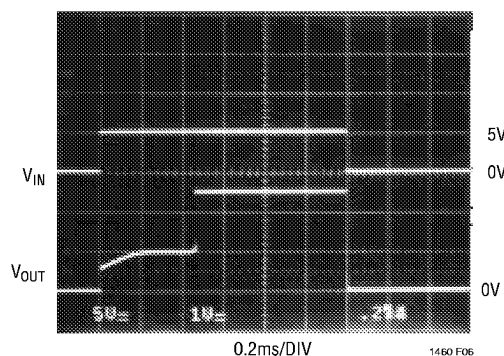
Figure 4. Isolation Resistor Test Circuit

APPLICATIONS INFORMATION

Figure 5. Effect of R_S for $C_L = 1\mu F$ Figure 7. $C_{BYPASS} = 0.1\mu F$

Fast Turn-On

It is recommended to add a $0.1\mu F$ or larger bypass capacitor to the input pin of the LT1460. Although this can help stability with large load currents, the main reason is for proper start-up. The LT1460 can start in $2\mu s$, but it is important to limit the dv/dt of the input. Under light load conditions and with a very fast input, internal nodes overslew and they require finite recovery time. Figure 6 shows the result of no bypass capacitance on the input and no output load. In this case the supply dv/dt is $5V$ in $30ns$ which causes internal overshoot, and the output does not bias to $2.5V$ until $500\mu s$. Figure 7 shows the effect of a $0.1\mu F$ bypass capacitor which limits the input dv/dt to approximately $5V$ in $2\mu s$ and the output settles cleanly in $4\mu s$.

Figure 6. $C_{BYPASS} = 0$

Output Accuracy

Like all references, either series or shunt, the error budget of the LT1460 is made up of primarily three components: initial accuracy, temperature coefficient and load regulation. Line regulation is neglected because it typically contributes only $30ppm/V$, or $75\mu V$ for a $1V$ input change. The LT1460 typically shifts less than 0.01% when soldered into a PCB, so this is also neglected. The output errors are calculated as follows for a $100\mu A$ load and $0^\circ C$ to $70^\circ C$ temperature range:

LT1460A

Initial accuracy = 0.075%

For $I_O = 100\mu A$,

$$\Delta V_{OUT} = \left(\frac{3500ppm}{mA} \right) (0.1mA) (2.5V) = 875\mu V$$

which is 0.035% .

For temperature $0^\circ C$ to $70^\circ C$ the maximum $\Delta T = 45^\circ C$,

$$\Delta V_{OUT} = \left(\frac{10ppm}{^\circ C} \right) (45^\circ C) (2.5V) = 1.125mV$$

which is 0.045% .

Total worst-case output error is:

$$0.075\% + 0.035\% + 0.045\% = 0.155\%.$$

Table 1 gives worst-case accuracy for LT1460A and LT1460B from $0^\circ C$ to $70^\circ C$.

APPLICATIONS INFORMATION

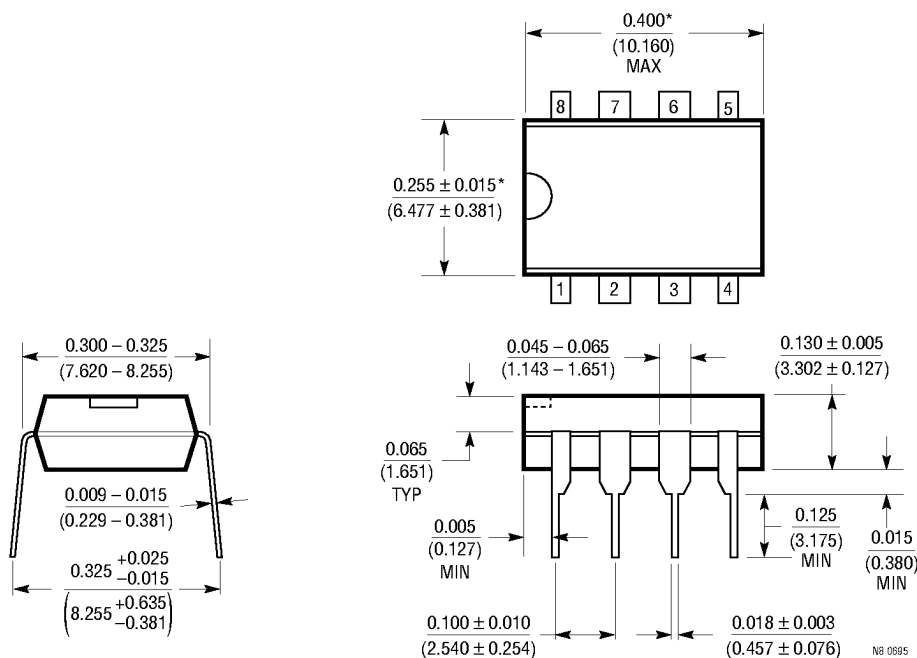
**Table 1. Worst-Case Output Accuracy
Over Temperature**

I_{OUT}	LT1460AC	LT1460BC
100 μ A	0.155%	0.225%
10mA	0.30%	0.37%
20mA	0.40%	0.47%

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

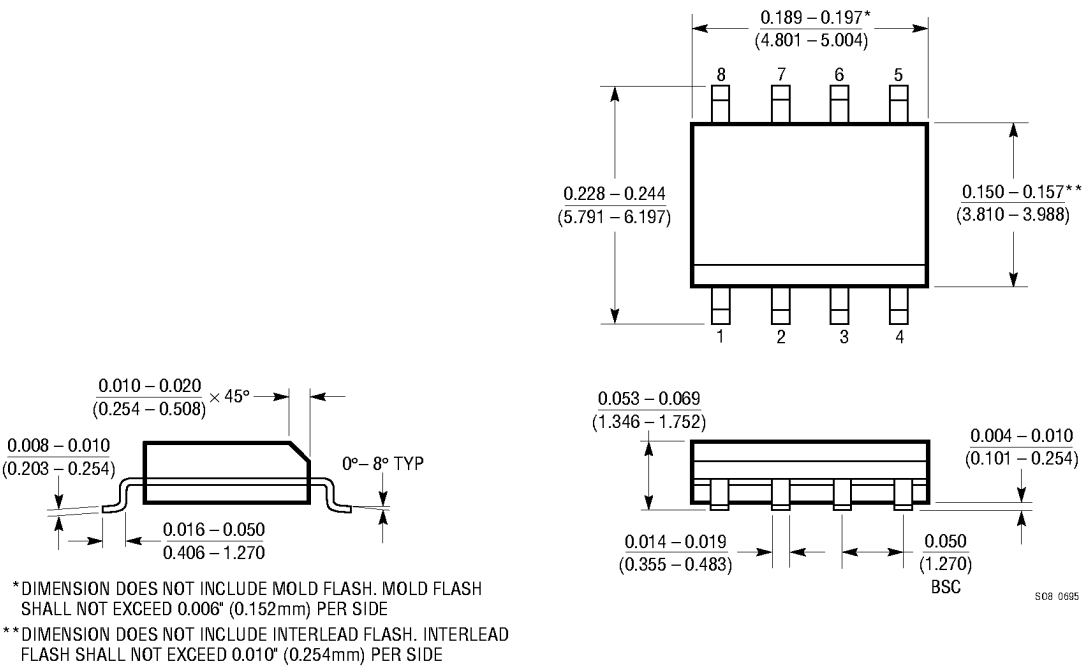
N8 Package
8-Lead PDIP (Narrow 0.300)
(LTC DWG # 05-08-1510)



*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

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

S8 Package
8-Lead Plastic Small Outline (Narrow 0.150)
(LTC DWG # 05-08-1610)



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1236	Precision Reference	0.05% Max, 5ppm/°C Max, SO Package
LT1019	Precision Bandgap Reference	0.05% Max, 5ppm/°C Max