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

DESCRIPTION

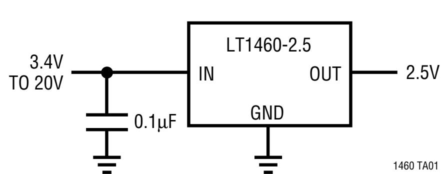
The LT®1460 is a micropower bandgap reference that combines very high accuracy and low drift with low power dissipation and small package size. This series reference uses curvature compensation to obtain low temperature coefficient and trimmed precision thin-film resistors to achieve high output accuracy. 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.

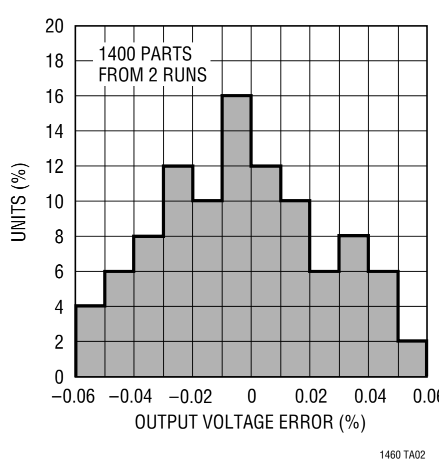
The LT1460 is available in 2.5V, 5V and 10V output voltages and comes in the 8-lead SO and PDIP packages.

TYPICAL APPLICATION

Basic Connection



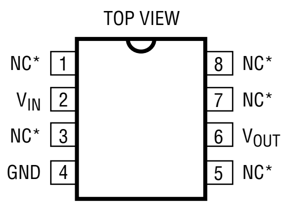
Typical Distribution of Output Voltage



ABSOLUTE MAXIMUM RATINGS

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

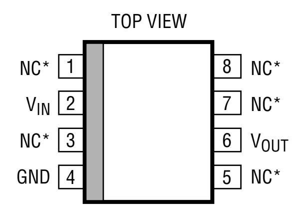
PACKAGE/ORDER INFORMATION



N8 PACKAGE
8-LEAD PDIP
*CONNECTED INTERNALLY.
DO NOT CONNECT EXTERNAL
CIRCUITRY TO THESE PINS

T_{JMAX} = 125°C, θ_{JA} = 130°C/W

ORDER PART NUMBER
LT1460ACN8-2.5
LT1460BCN8-2.5



S8 PACKAGE
8-LEAD PLASTIC SO
*CONNECTED INTERNALLY.
DO NOT CONNECT EXTERNAL
CIRCUITRY TO THESE PINS

T_{JMAX} = 125°C, θ_{JA} = 190°C/W

ORDER PART NUMBER
LT1460ACS8-2.5
LT1460BCS8-2.5

S8 PART MARKING
1460A2
1460B2

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)	$T_{MIN} \le T_J \le T_{MAX}$ LT1460A LT1460B			 5 10	 10 20	 ppm/°C ppm/°C
Line Regulation	$(V_{OUT} + 0.9V) \le V_{IN} \le (V_{OUT} + 2.5V)$	 ●		30	60 80	ppm/V ppm/V
	$(V_{OUT} + 2.5V) \le V_{IN} \le 20V$	 ●		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, $\Delta V_O \le 0.1\%$ $V_{IN} - V_{OUT}$, I_{OUT} = 10mA, $\Delta V_O \le 0.1\%$ $V_{IN} - V_{OUT}$, I_{OUT} = 10mA, $\Delta V_O \le 0.1\%$	● ● ●			0.9 1.3 1.4	V V V

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 Current	Short V_{OUT} to GND		25	40		mA
Reverse Leakage	V_{IN} = –20V	●		0.5	10	µA
Supply Current				100	130	µA
		●			165	µA
Output Voltage Noise (Note 6)	0.1Hz ≤ f ≤ 10Hz			4		$ppm_{(P-P)}$
Hysteresis (Note 7)	ΔT = –40°C to 85°C			160		ppm
	ΔT = 0°C to 70°C			25		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°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.

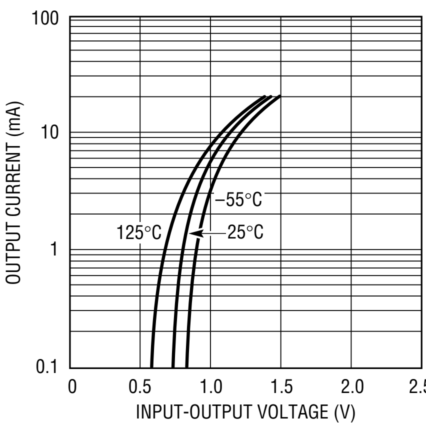
Note 5: Excludes load regulation errors.

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

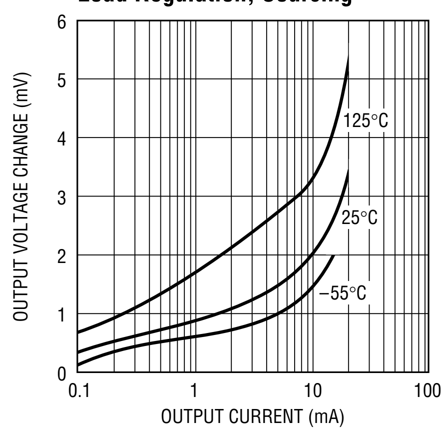
Note 7: Hysteresis in output voltage is created by package stress that differs depending on whether the IC was previously at a higher or lower temperature. Output voltage is always measured at 25°C, but the IC is cycled to 85°C or –40°C before successive measurements. Hysteresis is roughly proportional 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

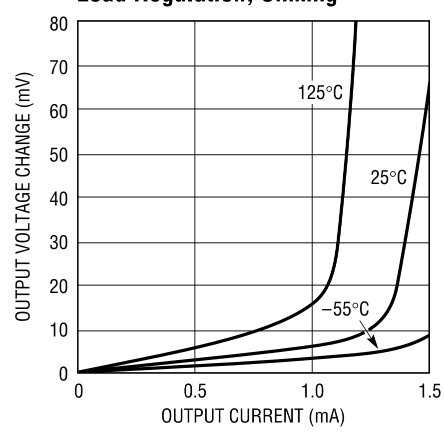
Minimum Input-Output Voltage Differential



LT1460-2.5 Load Regulation, Sourcing

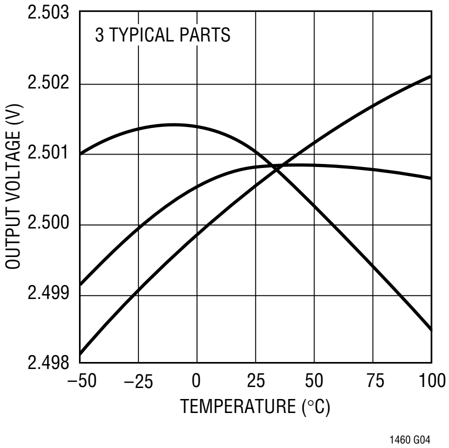


LT1460-2.5 Load Regulation, Sinking

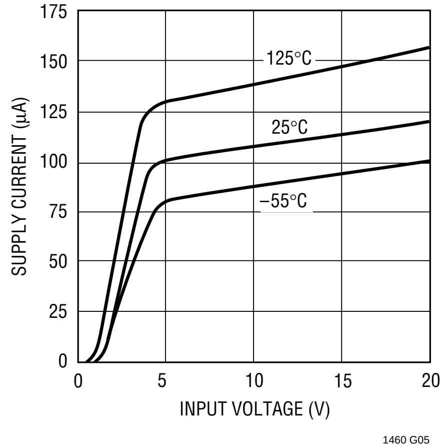


TYPICAL PERFORMANCE CHARACTERISTICS

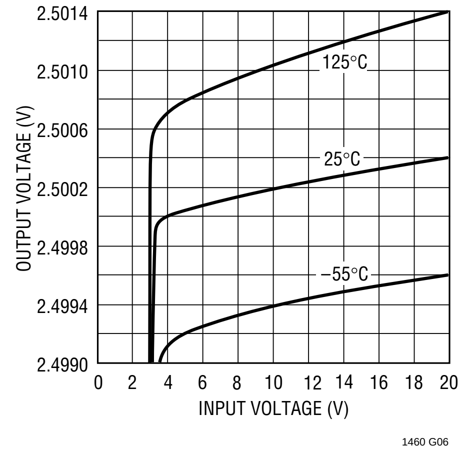
Output Voltage Temperature Drift



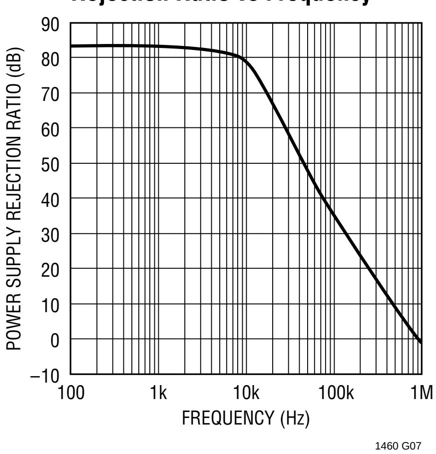
Supply Current vs Input Voltage



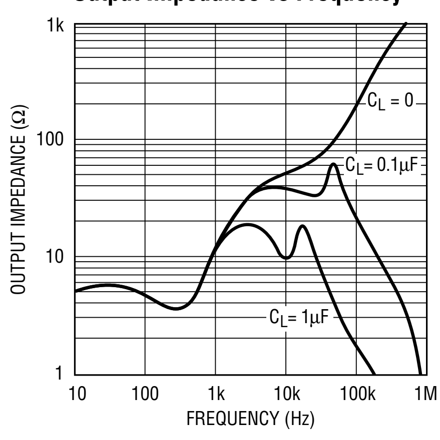
Line Regulation



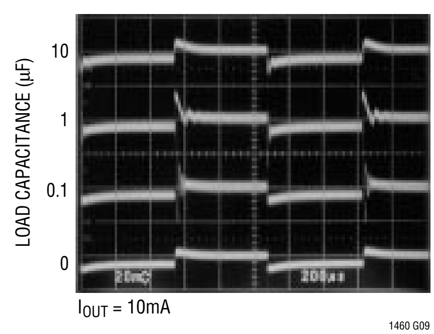
LT1460-2.5 Power Supply Rejection Ratio vs Frequency



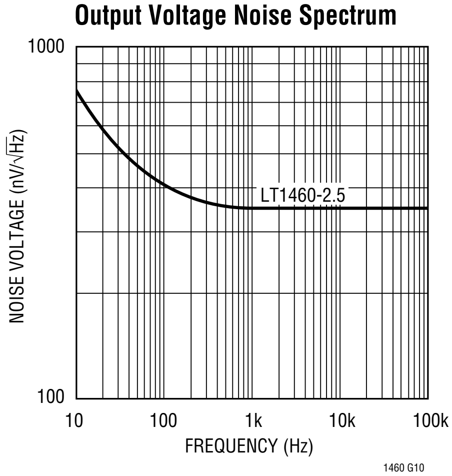
LT1460-2.5 Output Impedance vs Frequency



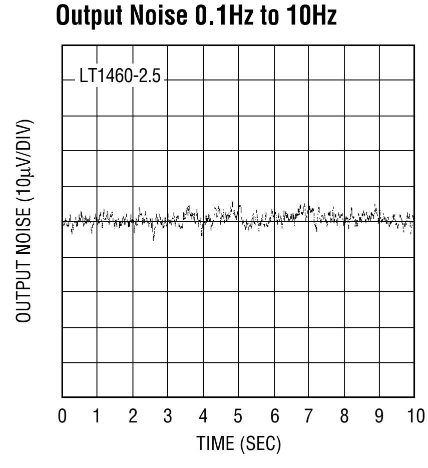
Transient Responses



Output Voltage Noise Spectrum



Output Noise 0.1Hz to 10Hz



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 500µW 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 100µA 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 1µs for a 100µA pulse and to 0.1% in 1.5µs with a 1mA step.

When load capacitance is greater than 0.01µF, 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 100µA load transient with a 0.01µF load capacitor. The ringing will be greatly reduced with a DC load as small as 200µA. With large output capacitors, ≥ 1µF, 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 = 1µF. R_S should not be made arbitrarily large because it will limit the load regulation.

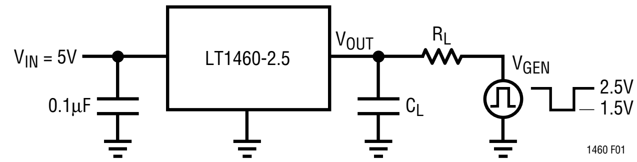


Figure 1. Response Time Test Circuit

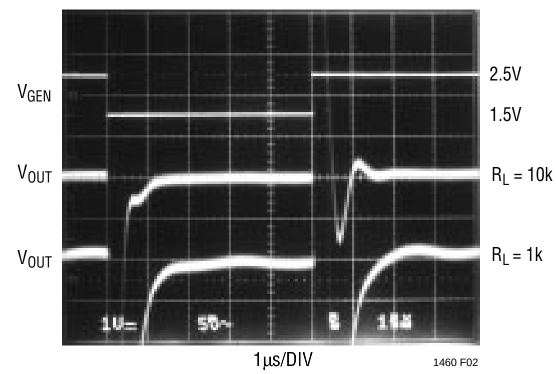


Figure 2. $C_L = 0$

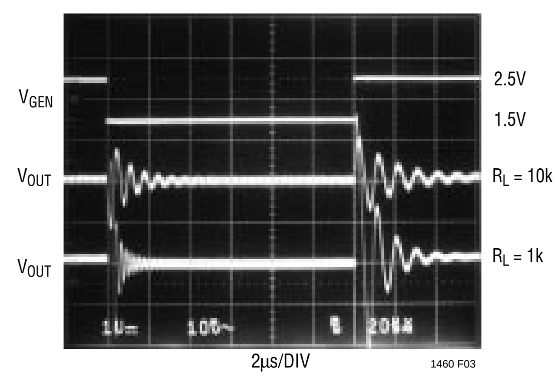


Figure 3. C_L = 0.01µF

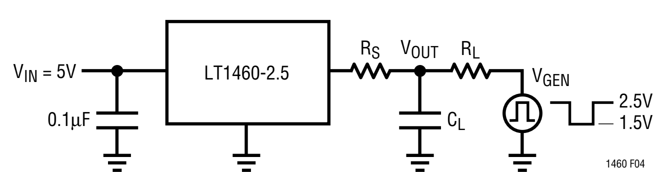


Figure 4. Isolation Resistor Test Circuit

APPLICATIONS INFORMATION

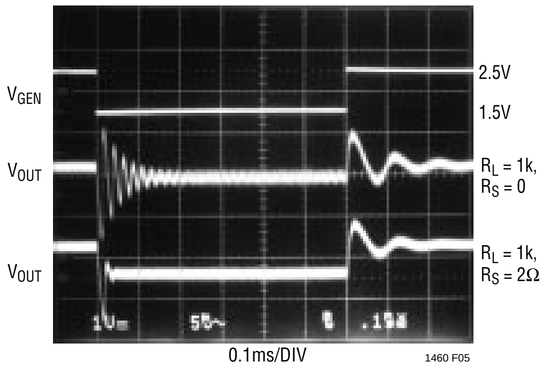


Figure 5. Effect of R_S for C_L = 1μF

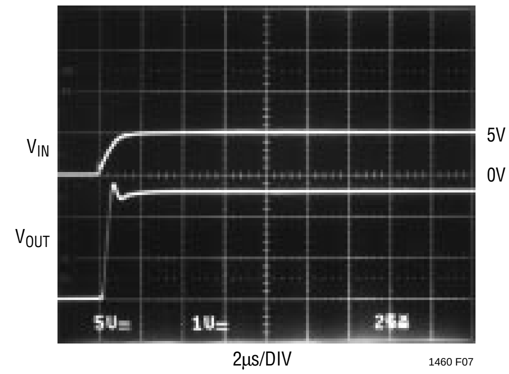


Figure 7. C_{BYPASS} = 0.1μF

Fast Turn-On

It is recommended to add a 0.1μF 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 2μs, 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 overslew, and the output does not bias to 2.5V until 500μs. Figure 7 shows the effect of a 0.1μF bypass capacitor which limits the input dv/dt to approximately 5V in 2μs and the output settles cleanly in 4μs.

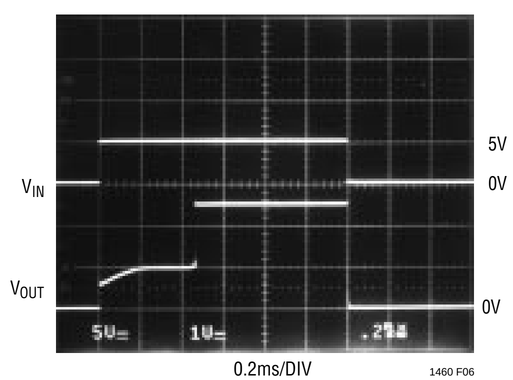


Figure 6. C_{BYPASS} = 0

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 75μV 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 100μA load and 0°C to 70°C temperature range:

LT1460A

Initial accuracy = 0.075%

For I_O = 100μA,

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

which is 0.035%.

For temperature 0°C to 70°C the maximum ΔT = 45°C,

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

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°C to 70°C.

APPLICATIONS INFORMATION

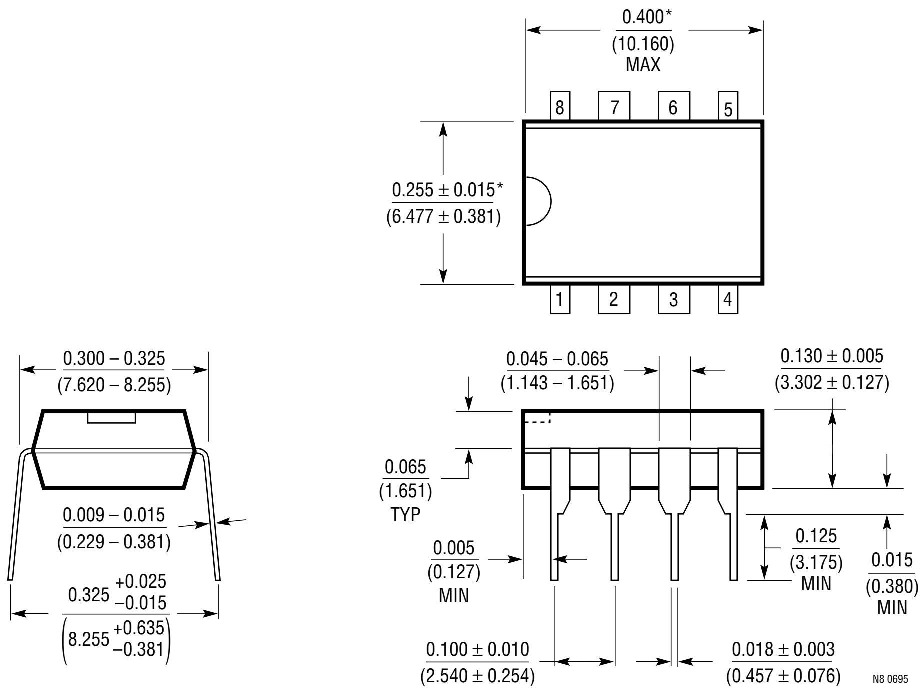
Table 1. Worst-Case Output Accuracy Over Temperature

I_{OUT}	LT1460AC	LT1460BC
100μA	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)

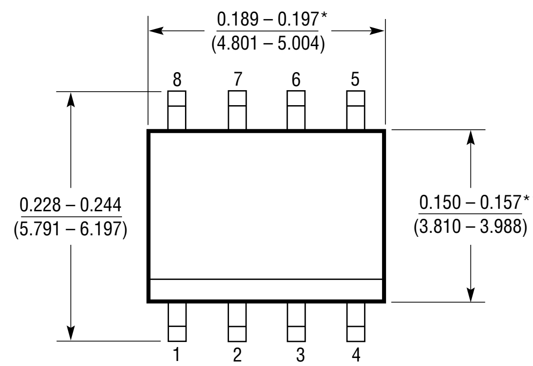


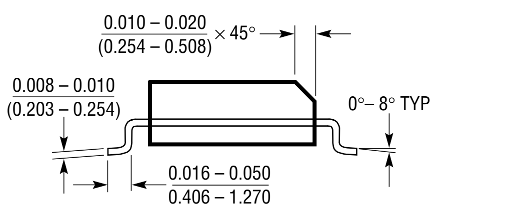
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

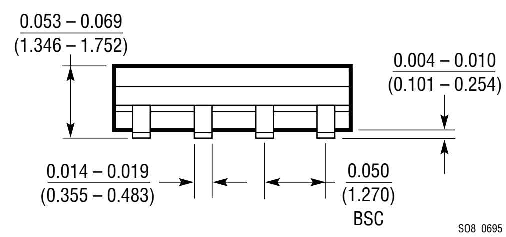
PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

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







*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

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

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