Micropower Precision Series Reference Family

FEATURES

- **Trimmed to High Accuracy: 0.075% Max**
- **Low Drift: 10ppm/°C Max**
- **Industrial Temperature Range**
- **Temperature Coefficient Guaranteed to 125°C**
- Low Supply Current: 130μA Max (LT1460-2.5)
- Minimum Output Current: 20mA
- No Output Capacitor Required
- Reverse Battery Protection
- Minimum Input/Output Differential: 0.9V
- Available in SO-8, MSOP-8, PDIP-8, TO-92 and SOT- 23 Package

APPLICATIONS

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

DESCRIPTION

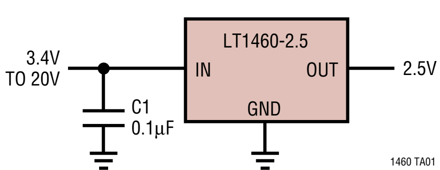
The LT®1460 is a micropower bandgap reference that combines very high accuracy and low drift with low power dissipation and small package size. This series reference uses curvature compensation to obtain low temperature coefficient and trimmed precision thin-film resistors to achieve high output accuracy.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

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, yet is stable with capacitive loads. This feature is important where PC board space is a premium or fast settling is demanded. In the event of a reverse battery connection, these references will not conduct current, and are therefore protected from damage.

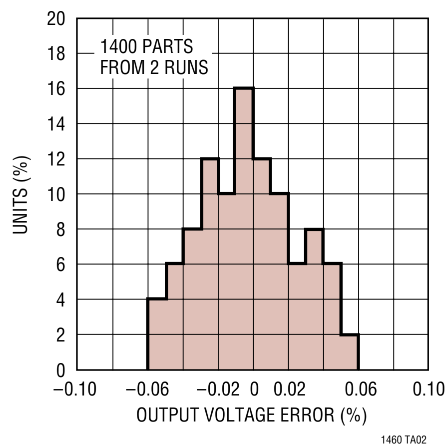
The LT1460 is available in the 8-lead MSOP, SO, PDIP and the 3-lead TO-92 and SOT23 packages.

TYPICAL APPLICATION

Basic Connection



Typical Distribution of Output Voltage S8 Package



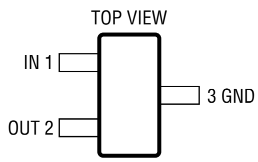
ABSOLUTE MAXIMUM RATINGS

(Note 1)

Input Voltage..30V
Reverse Voltage ....–15V
Output Short-Circuit Duration, T_A = 25°C
V_{IN} > 10V ....5 sec
V_{IN} ≤ 10V .... Indefinite

Specified Temperature Range
Commercial (C)....................................... 0°C to 70°C
Industrial (I).. –40°C to 85°C
High (H).. –40°C to 125°C
Storage Temperature Range (Note 2)..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PACKAGE/ORDER INFORMATION

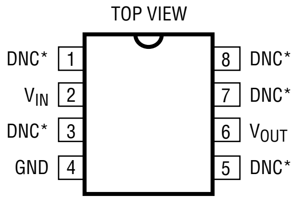


S3 PACKAGE
3-LEAD PLASTIC SOT-23
T_{JMAX} = 125°C, θ_{JA} = 325°C/W

ORDER PART NUMBER	S3 PART MARKING†
LT1460HCS3-2.5	LTAC
LT1460JCS3-2.5	LTAD } OR LTH8*
LT1460KCS3-2.5	LTAE
LT1460HCS3-3	LTAN
LT1460JCS3-3	LTAP } OR LTH9*
LT1460KCS3-3	LTAQ
LT1460HCS3-3.3	LTAR
LT1460JCS3-3.3	LTAS } OR LTJ1*
LT1460KCS3-3.3	LTAT
LT1460HCS3-5	LTAK
LT1460JCS3-5	LTAL } OR LTJ2*
LT1460KCS3-5	LTAM
LT1460HCS3-10	LTAU
LT1460JCS3-10	LTAV } OR LTJ3*
LT1460KCS3-10	LTAW

*The temperature grades and parametric grades are identified by a label on the shipping container. †Product may be identified with either part marking.

PACKAGE/ORDER INFORMATION

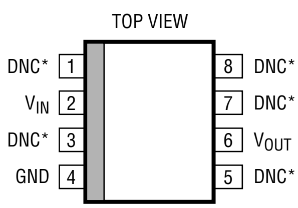


N8 PACKAGE
8-LEAD PLASTIC DIP

*CONNECTED INTERNALLY.
DO NOT CONNECT EXTERNAL CIRCUITRY TO THESE PINS

$T_{JMAX} = 150°C$, $\theta_{JA} = 130°C/W$

ORDER PART NUMBER
LT1460ACN8-2.5 LT1460BIN8-2.5 LT1460DCN8-2.5 LT1460EIN8-2.5
LT1460ACN8-5 LT1460BIN8-5 LT1460DCN8-5 LT1460EIN8-5
LT1460ACN8-10 LT1460BIN8-10 LT1460DCN8-10 LT1460EIN8-10



S8 PACKAGE
8-LEAD PLASTIC SO

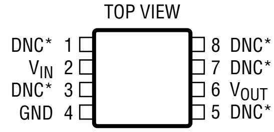
*CONNECTED INTERNALLY.
DO NOT CONNECT EXTERNAL CIRCUITRY TO THESE PINS

$T_{JMAX} = 150°C$, $\theta_{JA} = 190°C/W$

ORDER PART NUMBER	S8 PART MARKING
LT1460ACS8-2.5	1460A2
LT1460BIS8-2.5	460BI2
LT1460DCS8-2.5	1460D2
LT1460EIS8-2.5	460EI2
LT1460LHS8-2.5	60LH25
LT1460MHS8-2.5	60MH25
LT1460ACS8-5	1460A5
LT1460BIS8-5	460BI5
LT1460DCS8-5	1460D5
LT1460EIS8-5	460EI5
LT1460LHS8-5	460LH5
LT1460MHS8-5	460MH5
LT1460ACS8-10	1460A1
LT1460BIS8-10	460BI1
LT1460DCS8-10	1460D1
LT1460EIS8-10	460EI1

PACKAGE/ORDER INFORMATION

TOP VIEW

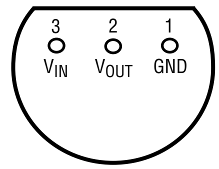


MS8 PACKAGE
8-LEAD PLASTIC MSOP

*CONNECTED INTERNALLY.
DO NOT CONNECT EXTERNAL
CIRCUITRY TO THESE PINS

$T_{JMAX} = 150°C$, $\theta_{JA} = 250°C/W$

BOTTOM VIEW



Z PACKAGE
3-LEAD TO-92 PLASTIC

$T_{JMAX} = 150°C$, $\theta_{JA} = 160°C/W$

ORDER PART NUMBER	MS8 PART MARKING	ORDER PART NUMBER
LT1460CCMS8-2.5	LTAA	LT1460GCZ-2.5
LT1460FCMS8-2.5	LTAB	LT1460GIZ-2.5
LT1460CCMS8-5	LTAF	LT1460GCZ-5
LT1460FCMS8-5	LTAG	LT1460GIZ-5
LT1460CCMS8-10	LTAH	LT1460GCZ-10
LT1460FCMS8-10	LTAJ	LT1460GIZ-10

Order Options Tape and Reel: Add #TR
Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF
Lead Free Part Marking: http://www.linear.com/leadfree/

Consult LTC Marketing for parts specified with wider operating temperature ranges.

AVAILABLE OPTIONS

TEMPERATURE	ACCURACY (%)	TEMPERATURE COEFFICIENT (ppm/°C)	PACKAGE TYPE				
			N8	S8	MS8	Z	S3
0°C to 70°C	0.075	10	LT1460ACN8	LT1460ACS8			
–40°C to 85°C	0.10	10	LT1460BIN8	LT1460BIS8			
0°C to 70°C	0.10	15			LT1460CCMS8		
0°C to 70°C	0.10	20	LT1460DCN8	LT1460DCS8			
–40°C to 85°C	0.125	20	LT1460EIN8	LT1460EIS8			
0°C to 70°C	0.15	25			LT1460FCMS8		
0°C to 70°C	0.25	25				LT1460GCZ	
–40°C to 85°C	0.25	25				LT1460GIZ	
–40°C to 85°C/125°C	0.20	20/50		LT1460LHS8			
–40°C to 125°C	0.20	50		LT1460MHS8			
0°C to 70°C	0.20	20					LT1460HCS3
0°C to 70°C	0.40	20					LT1460JCS3
0°C to 70°C	0.50	50					LT1460KCS3

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = V_{OUT} + 2.5V, I_{OUT} = 0 unless otherwise specified.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage	LT1460ACN8-2.5, ACS8-2.5		2.49813 –0.075		2.50188 0.075	V %
	LT1460BIN8-2.5, BIS8-2.5, CCMS8-2.5, DCN8-2.5, DCS8-2.5		2.4975 –0.10		2.5025 0.10	V %
	LT1460EIN8-2.5, EIS8-2.5		2.49688 –0.125		2.50313 0.125	V %
	LT1460FCMS8-2.5		2.49625 –0.15		2.50375 0.15	V %
	LT1460GCZ-2.5, GIZ-2.5		2.49375 –0.25		2.50625 0.25	V %
	LT1460LHS8-2.5, MHS8-2.5		2.495 –0.20		2.505 0.20	V %
	LT1460ACN8-5, ACS8-5		4.99625 –0.075		5.00375 0.075	V %
	LT1460BIN8-5, BIS8-5, CCMS8-5, DCN8-5, DCS8-5		4.995 –0.10		5.005 0.10	V %
	LT1460EIN8-5, EIS8-5		4.99375 –0.125		5.00625 0.125	V %
	LT1460FCMS8-5		4.9925 –0.15		5.0075 0.15	V %
	LT1460GCZ-5, GIZ-5		4.9875 –0.25		5.0125 0.25	V %
	LT1460LHS8-5, MHS8-5		4.990 –0.20		5.010 0.20	V %
	LT1460ACN8-10, ACS8-10		9.9925 –0.075		10.0075 0.075	V %
	LT1460BIN8-10, BIS8-10, CCMS8-10, DCN8-10, DCS8-10		9.990 –0.10		10.010 0.10	V %
	LT1460EIN8-10, EIS8-10		9.9875 –0.125		10.0125 0.125	V %
	LT1460FCMS8-10		9.985 –0.15		10.0015 0.15	V %
	LT1460GCZ-10, GIZ-10		9.975 –0.25		10.025 0.25	V %
	LT1460HC LT1460JC LT1460KC		–0.2 –0.4 –0.5		0.2 0.4 0.5	% % %
Output Voltage Temperature Coefficient (Note 3)	$T_{MIN} \le T_J \le T_{MAX}$ LT1460ACN8, ACS8, BIN8, BIS8 LT1460CCMS8 LT1460DCN8, DCS8, EIN8, EIS8 LT1460FCMS8, GCZ, GIZ LT1460LHS8 –40°C to 85°C –40°C to 125°C LT1460MHS8 –40°C to 125°C	 ● ● ● ● ● ● ●		 5 7 10 12 10 25 25	 10 15 20 25 20 50 50	 ppm/°C ppm/°C ppm/°C ppm/°C ppm/°C ppm/°C ppm/°C
	LT1460HC LT1460JC LT1460KC	● ● ●		10 10 25	20 20 50	ppm/°C ppm/°C ppm/°C

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = V_{OUT} + 2.5V, I_{OUT} = 0 unless otherwise specified.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Line Regulation LT1460A, LT1460B, LT1460C, LT1460D, LT1460E, LT1460F, LT1460G, LT1460H, LT1460L, LT1460M	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
LT1460HC, LT1460JC, LT1460KC	V_{OUT} + 0.9V ≤ V_{IN} ≤ V_{OUT} + 2.5V	 ●		150	800 1000	ppm/V ppm/V
	V_{OUT} + 2.5V ≤ V_{IN} ≤ 20V	 ●		50	100 130	ppm/V ppm/V
Load Regulation Sourcing (Note 4) LT1460A, LT1460B, LT1460C, LT1460D, LT1460E, LT1460F, LT1460G, LT1460H, LT1460L, LT1460M	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 to 70°C	 ●		70	100 140	ppm/mA ppm/mA
LT1460HC, LT1460JC, LT1460KC	I_{OUT} = 100µA	 ●		1000	3000 4000	ppm/mA ppm/mA
	I_{OUT} = 10mA	 ●		50	200 300	ppm/mA ppm/mA
	I_{OUT} = 20mA	 ●		20	70 100	ppm/mA ppm/mA
Thermal Regulation (Note 5) LT1460A, LT1460B, LT1460C, LT1460D, LT1460E, LT1460F, LT1460G, LT1460H, LT1460L, LT1460M	ΔP = 200mW			0.5	2.5	ppm/mW
LT1460HC, LT1460JC, LT1460KC	ΔP = 200mW			2.5	10	ppm/mW
Dropout Voltage (Note 6)	V_{IN} – V_{OUT}, I_{OUT} = 0	●			0.9	V
	V_{IN} – V_{OUT}, I_{OUT} = 10mA	 ●			1.3 1.4	V V
Output Current	Short V_{OUT} to GND			40		mA
Reverse Leakage	V_{IN} = –15V	●		0.5	10	µA
Supply Current	LT1460-2.5	 ●		100	130 165	µA µA
	LT1460-5	 ●		125	175 225	µA µA
	LT1460-10	 ●		190	270 360	µA µA
	LT1460S3-2.5	 ●		115	145 175	µA µA
	LT1460S3-3	 ●		145	180 220	µA µA
	LT1460S3-3.3	 ●		145	180 220	µA µA
	LT1460S3-5	 ●		160	200 240	µA µA
	LT1460S3-10	 ●		215	270 350	µA µA

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = V_{OUT} + 2.5V, I_{OUT} = 0 unless otherwise specified.

PARAMETER	CONDITIONS			MIN	TYP	MAX	UNITS
Output Voltage Noise (Note 7) LT1460A, LT1460B, LT1460C, LT1460D, LT1460E, LT1460F, LT1460G, LT1460H, LT1460L, LT1460M	LT1460-2.5	0.1Hz ≤ f ≤ 10Hz 10Hz ≤ f ≤ 1kHz			10 10		μV_{P-P} μV_{RMS}
	LT1460-5	0.1Hz ≤ f ≤ 10Hz 10Hz ≤ f ≤ 1kHz			20 20		μV_{P-P} μV_{RMS}
	LT1460-10	0.1Hz ≤ f ≤ 10Hz 10Hz ≤ f ≤ 1kHz			40 35		μV_{P-P} μV_{RMS}
LT1460HC, LT1460JC, LT1460KC	0.1Hz ≤ f ≤ 10Hz 10Hz ≤ f ≤ 1kHz				4 4		ppm (P-P) ppm (RMS)
Long-Term Stability of Output Voltage (Note 8) S8 Pkg					40		ppm/$\sqrt{kHr}$
LT1460HC, LT1460JC, LT1460KC					100		ppm/$\sqrt{kHr}$
Hysteresis (Note 9) LT1460A, LT1460B, LT1460C, LT1460D, LT1460E, LT1460F, LT1460G, LT1460H, LT1460L, LT1460M	ΔT = 0°C to 70°C ΔT = –40°C to 85°C				25 160		ppm ppm
LT1460HC, LT1460JC, LT1460KC	ΔT = 0°C to 70°C ΔT = –40°C to 85°C		● ●		50 250		ppm ppm

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: If the part is stored outside of the specified temperature range, the output may shift due to hysteresis.

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: Thermal regulation is caused by die temperature gradients created by load current or input voltage changes. This effect must be added to normal line or load regulation. This parameter is not 100% tested.

Note 6: Excludes load regulation errors. For LT1460S3, ΔV_{OUT} ≤ 0.2%. For all other packages, ΔV_{OUT} ≤ 0.1%.

Note 7: Peak-to-peak noise is measured with a single highpass filter at 0.1Hz and 2-pole lowpass filter at 10Hz. The unit is enclosed in a still-air environment to eliminate thermocouple effects on the leads. The test time is 10 sec. RMS noise is measured with a single highpass filter at 10Hz and a 2-pole lowpass filter at 1kHz. The resulting output is full wave rectified and then integrated for a fixed period, making the final reading an average as opposed to RMS. A correction factor of 1.1 is used to convert from average to RMS and a second correction of 0.88 is used to correct for the nonideal pass band of the filters.

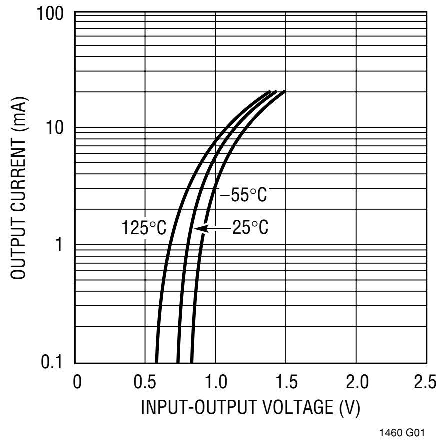
Note 8: Long-term stability typically has a logarithmic characteristic and therefore, changes after 1000 hours tend to be much smaller than before that time. Total drift in the second thousand hours is normally less than one third that of the first thousand hours with a continuing trend toward reduced drift with time. Significant improvement in long-term drift can be realized by preconditioning the IC with a 100 hour to 200 hour, 125°C burn-in. Long-term stability will also be affected by differential stresses between the IC and the board material created during board assembly. See PC Board Layout in the Applications Information section.

Note 9: 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. For instruments that are stored at reasonably well-controlled temperatures (within 20 or 30 degrees of operating temperature) hysteresis is generally not a problem.

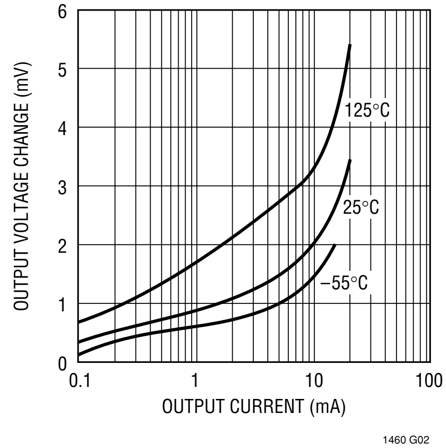
TYPICAL PERFORMANCE CHARACTERISTICS

LT1460-2.5 (N8, S8, MS8, Z Packages)

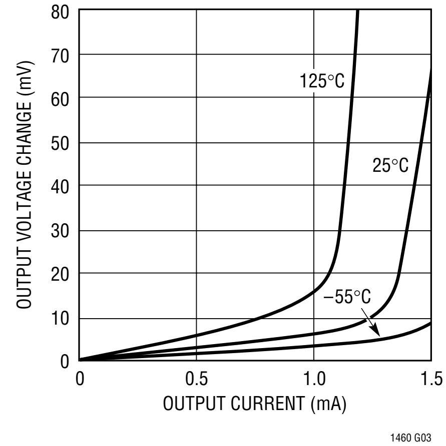
2.5V Minimum Input-Output Voltage Differential



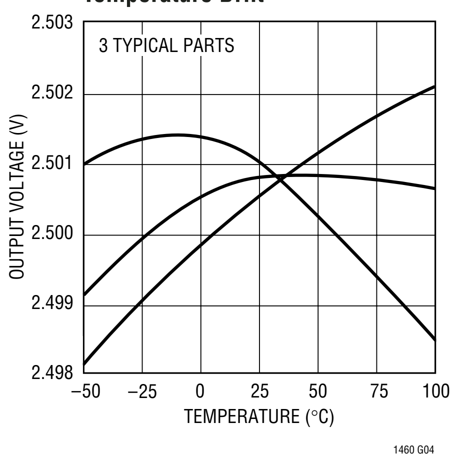
2.5V Load Regulation, Sourcing



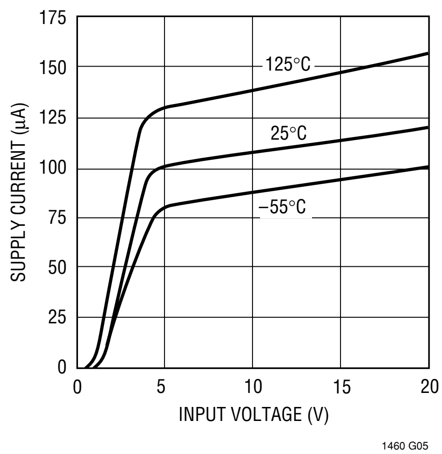
2.5V Load Regulation, Sinking



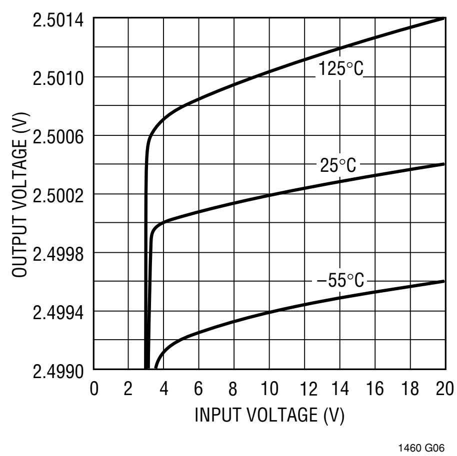
2.5V Output Voltage Temperature Drift



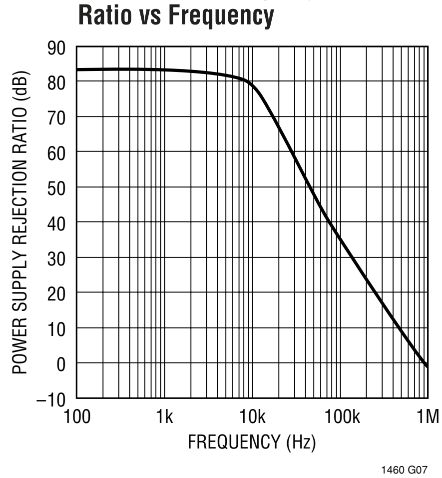
2.5V Supply Current vs Input Voltage



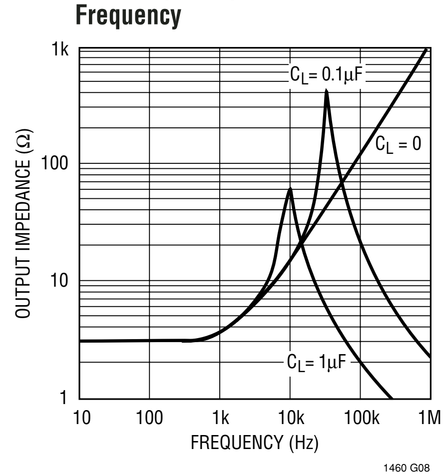
2.5V Line Regulation



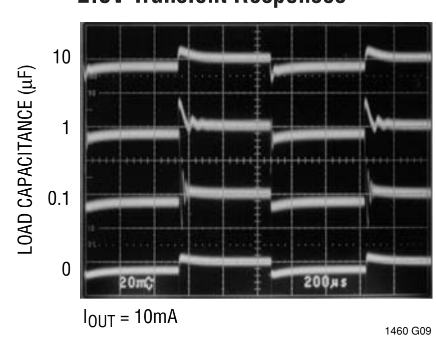
2.5V Power Supply Rejection Ratio vs Frequency



2.5V Output Impedance vs Frequency

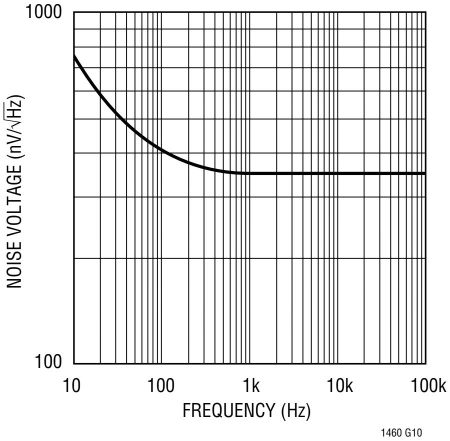


2.5V Transient Responses

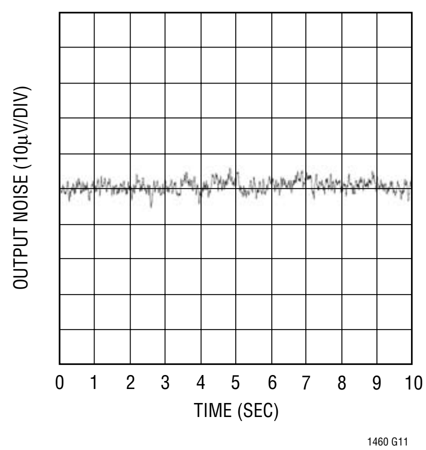


TYPICAL PERFORMANCE CHARACTERISTICS

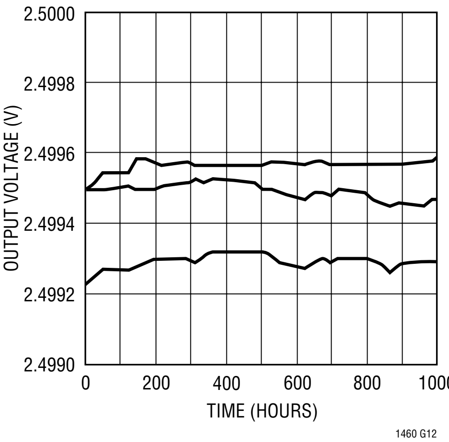
2.5V Output Voltage Noise Spectrum



2.5V Output Noise 0.1Hz to 10Hz

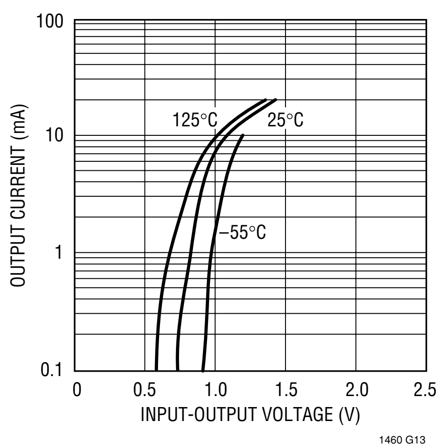


2.5V Long-Term Drift Three Typical Parts (S8 Package)

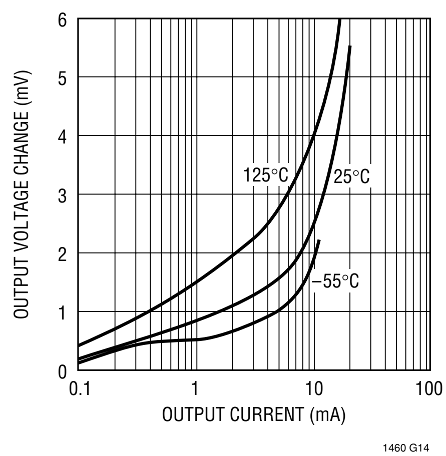


LT1460-5 (N8, S8, MS8, Z Packages)

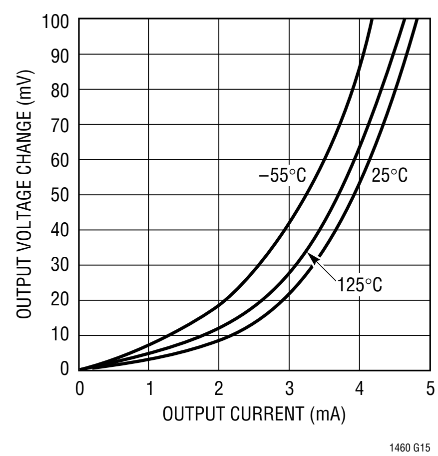
5V Minimum Input-Output Voltage Differential



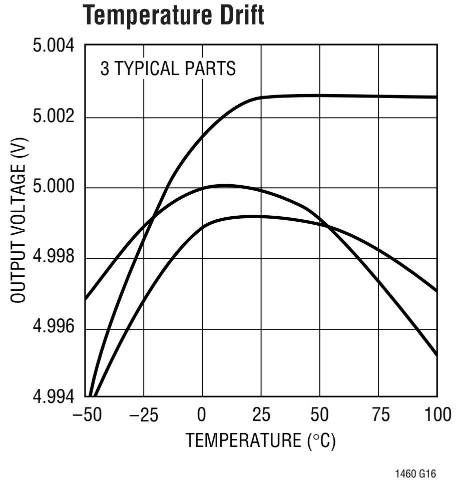
5V Load Regulation, Sourcing



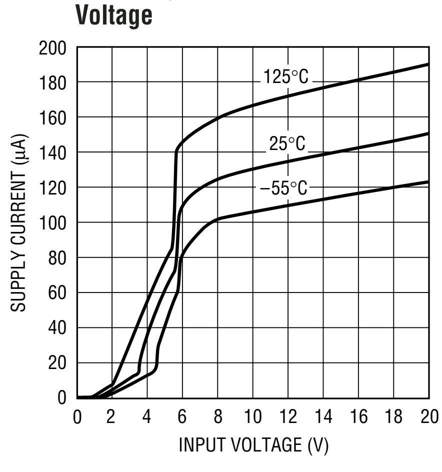
5V Load Regulation, Sinking



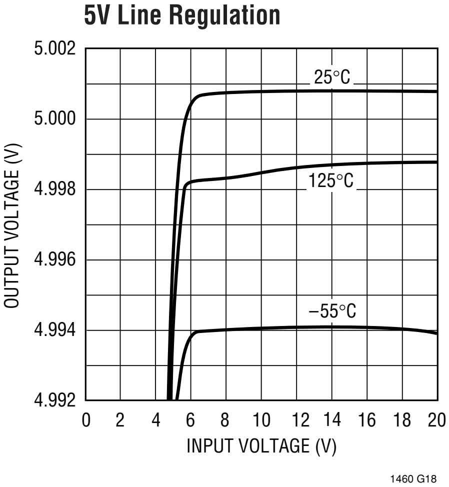
5V Output Voltage Temperature Drift



5V Supply Current vs Input Voltage



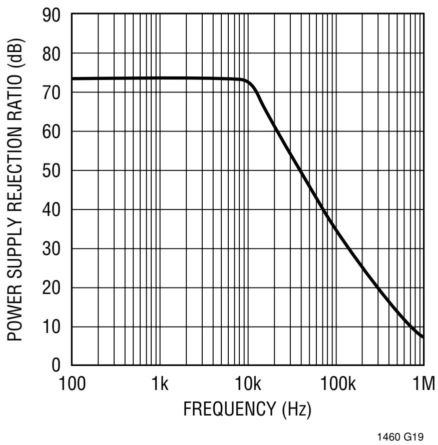
5V Line Regulation



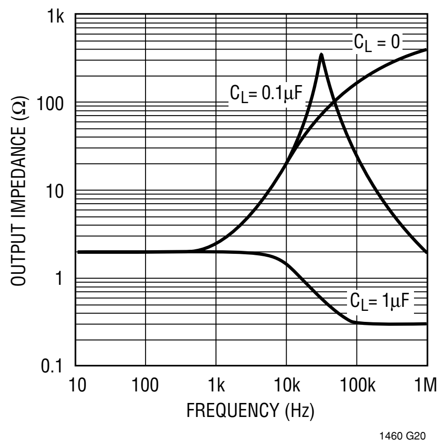
TYPICAL PERFORMANCE CHARACTERISTICS

LT1460-5 (N8, S8, MS8, Z Packages)

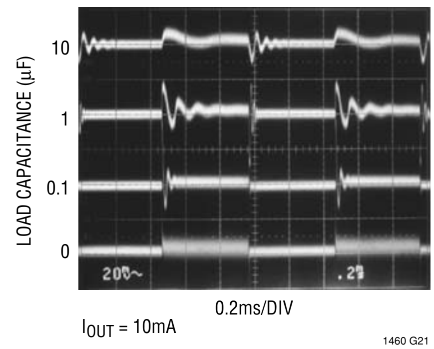
5V Power Supply Rejection Ratio vs Frequency



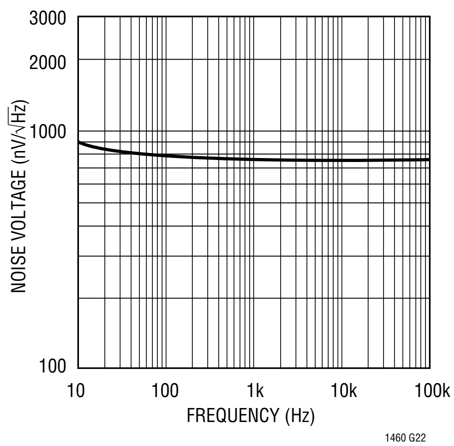
5V Output Impedance vs Frequency



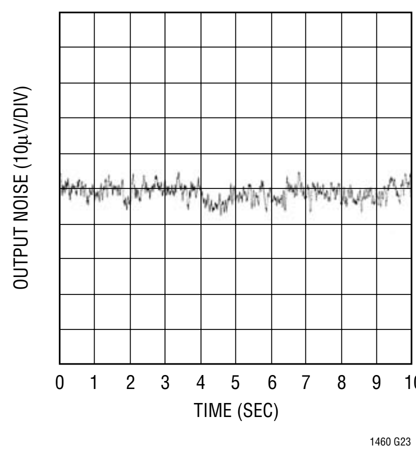
5V Transient Responses



5V Output Voltage Noise Spectrum

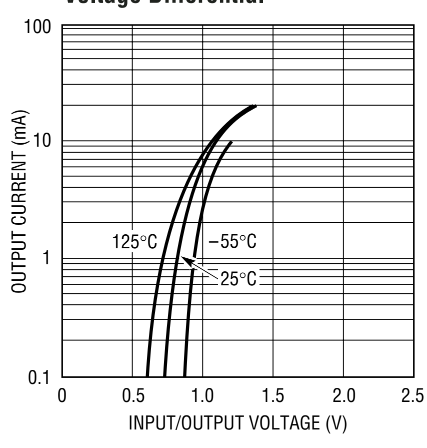


5V Output Noise 0.1Hz to 10Hz

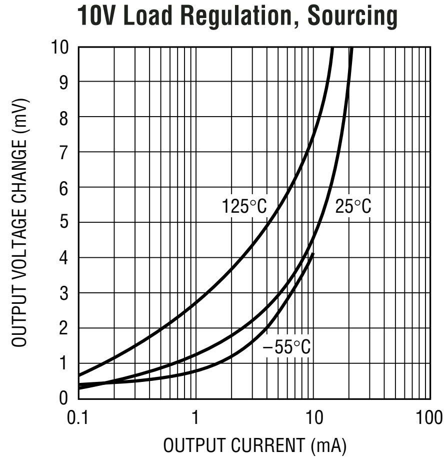


LT1460-10 (N8, S8, MS8, Z Packages)

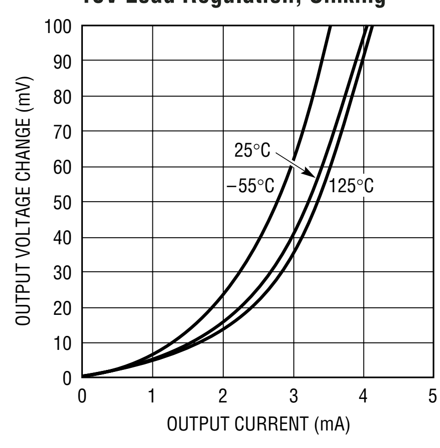
10V Minimum Input/Output Voltage Differential



10V Load Regulation, Sourcing

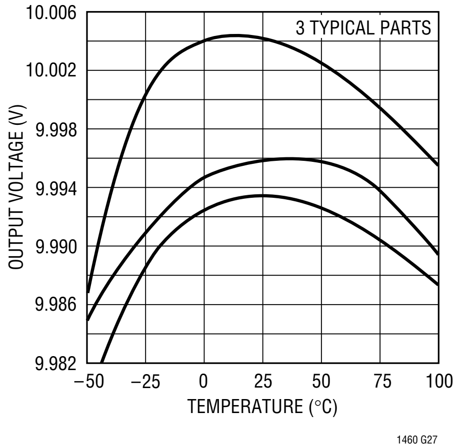


10V Load Regulation, Sinking

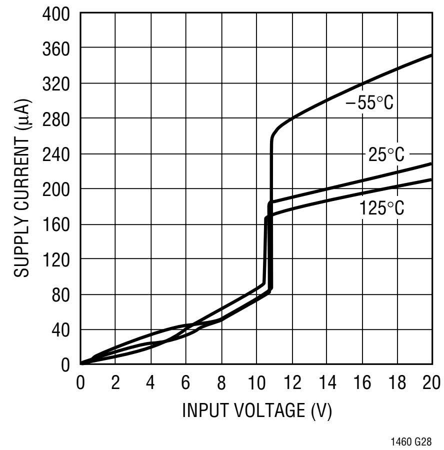


TYPICAL PERFORMANCE CHARACTERISTICS

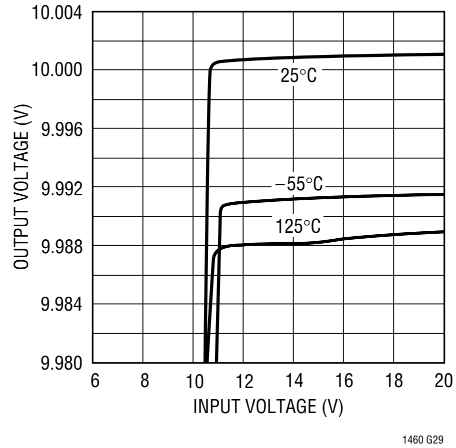
10V Output Voltage Temperature Drift



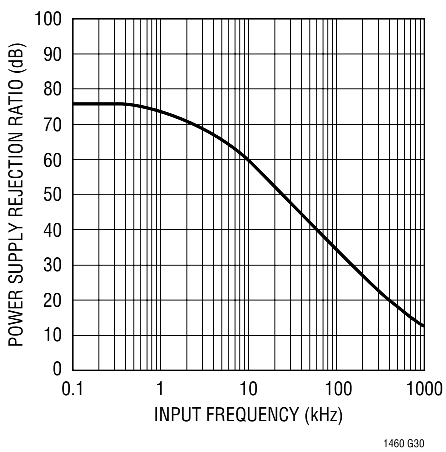
10V Supply Current vs Input Voltage



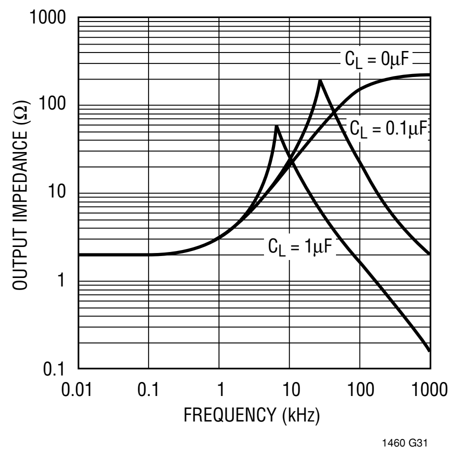
10V Line Regulation



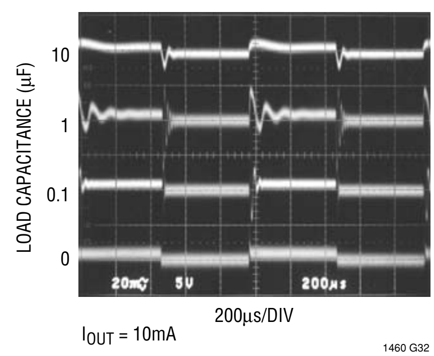
10V Power Supply Rejection Ratio vs Frequency



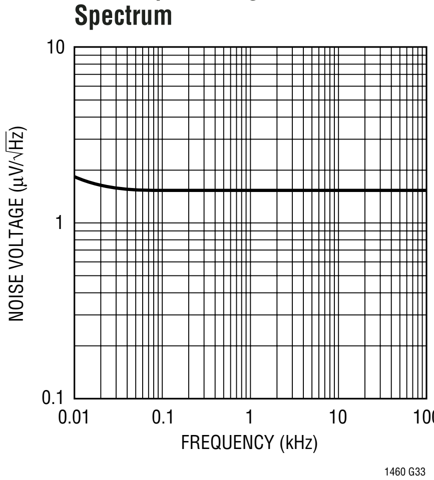
10V Output Impedance vs Frequency



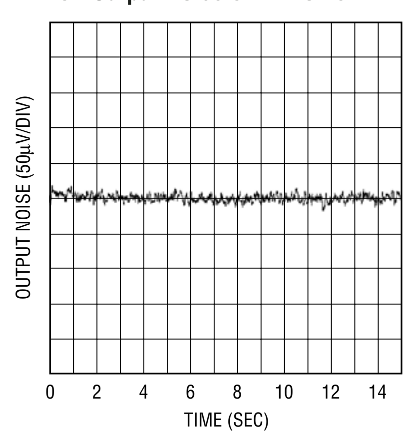
10V Transient Responses



10V Output Voltage Noise Spectrum



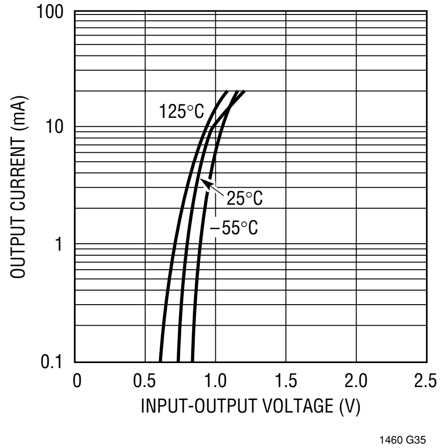
10V Output Noise 0.1Hz to 10Hz



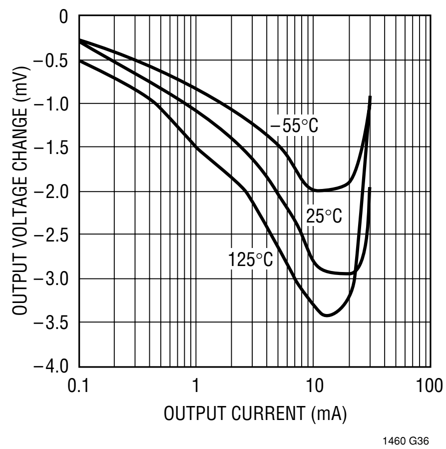
TYPICAL PERFORMANCE CHARACTERISTICS

Characteristic curves are similar for all voltage options of the LT1460S3. Curves from the LT1460S3-2.5 and the LT1460S3-10 represent the extremes of the voltage options. Characteristic curves for other output voltages fall between these curves, and can be estimated based on their voltage output.

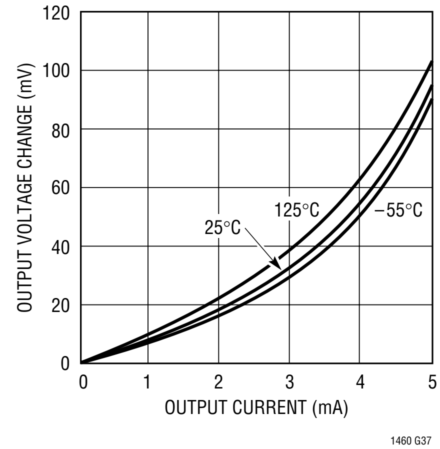
LT1460S3-2.5V Minimum Input-Output Voltage Differential



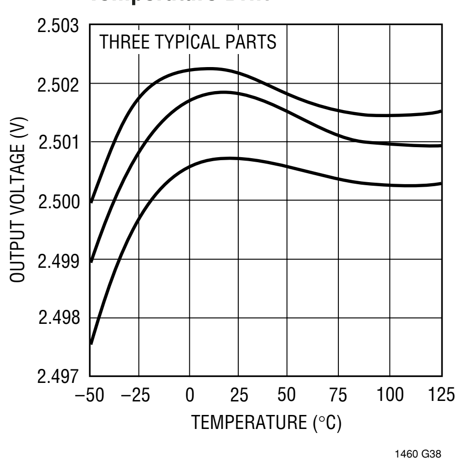
LT1460S3-2.5V Load Regulation, Sourcing



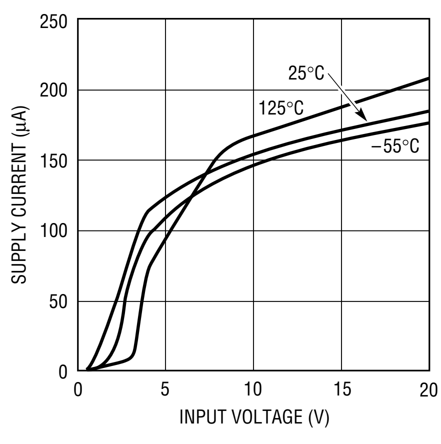
LT1460S3-2.5V Load Regulation, Sinking



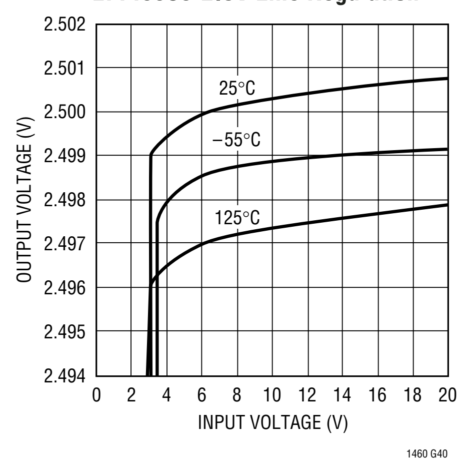
LT1460S3-2.5V Output Voltage Temperature Drift



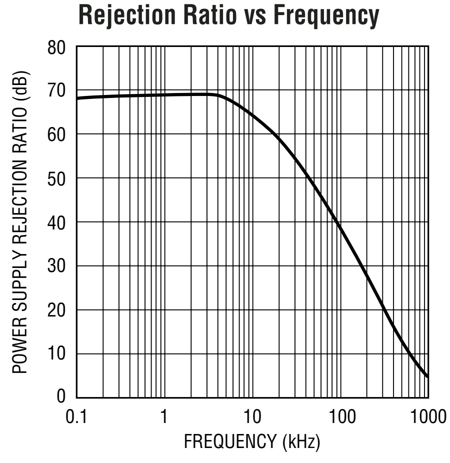
LT1460S3-2.5V Supply Current vs Input Voltage



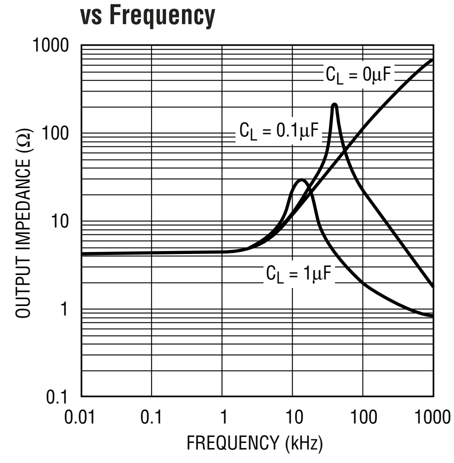
LT1460S3-2.5V Line Regulation



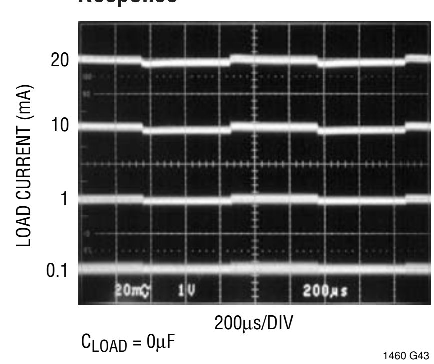
LT1460S3-2.5V Power Supply Rejection Ratio vs Frequency



LT1460S3-2.5V Output Impedance vs Frequency



LT1460S3-2.5V Transient Response



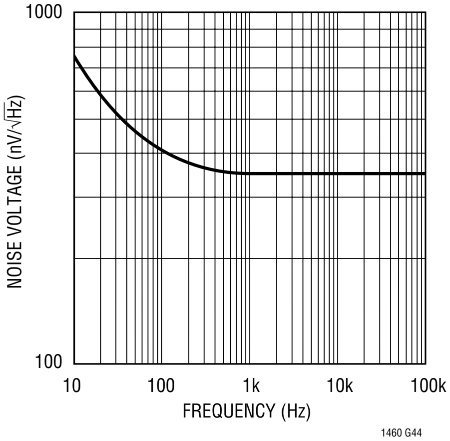
1460f

LINEAR TECHNOLOGY

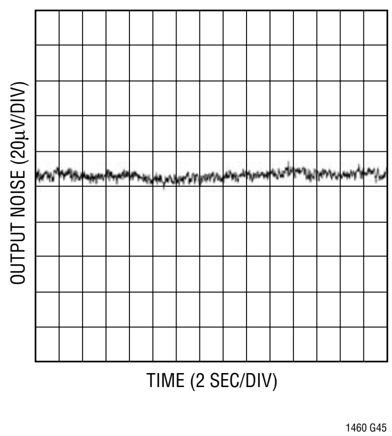
TYPICAL PERFORMANCE CHARACTERISTICS

Characteristic curves are similar for all voltage options of the LT1460S3. Curves from the LT1460S3-2.5 and the LT1460S3-10 represent the extremes of the voltage options. Characteristic curves for other output voltages fall between these curves, and can be estimated based on their voltage output.

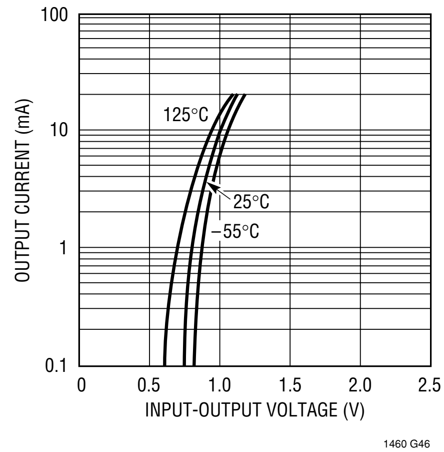
LT1460S3-2.5V Output Voltage Noise Spectrum



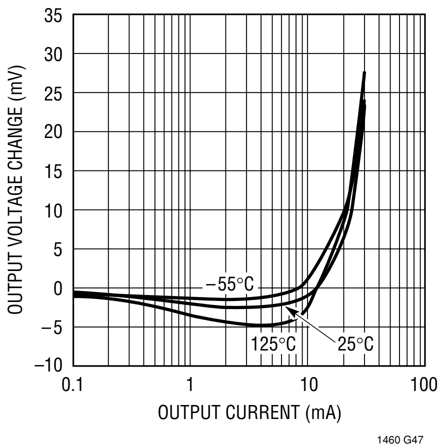
LT1460S3-2.5V Output Noise 0.1Hz to 10Hz



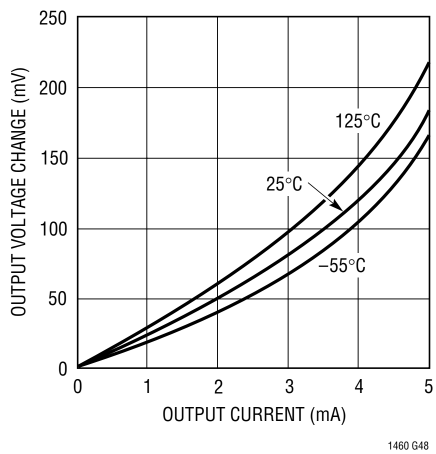
LT1460S3-10V Minimum Input-Output Voltage Differential



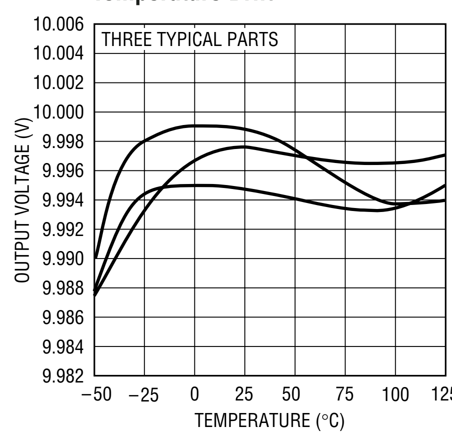
LT1460S3-10V Load Regulation, Sourcing



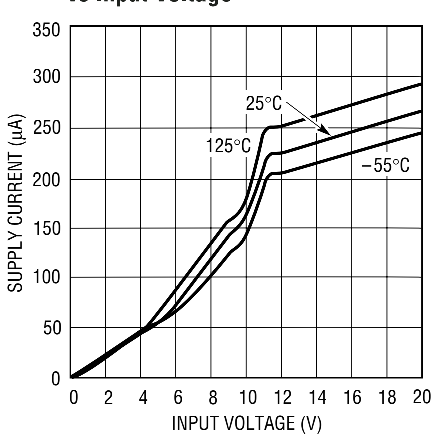
LT1460S3-10V Load Regulation, Sinking



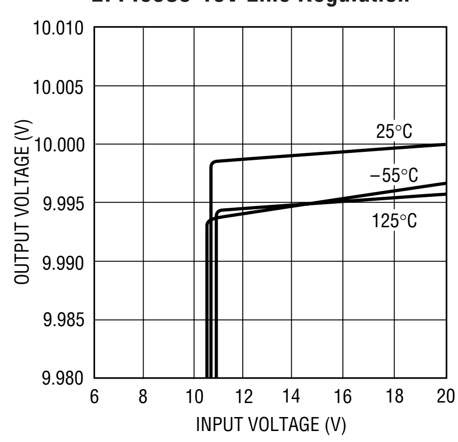
LT1460S3-10V Output Voltage Temperature Drift



LT1460S3-10V Supply Current vs Input Voltage



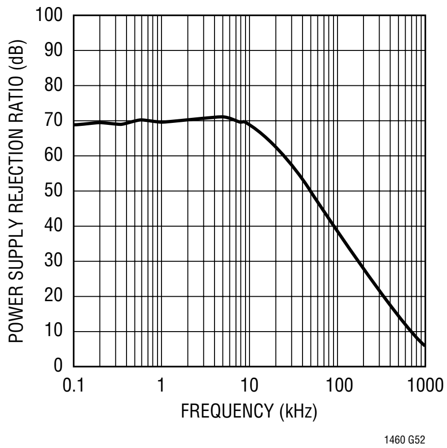
LT1460S3-10V Line Regulation



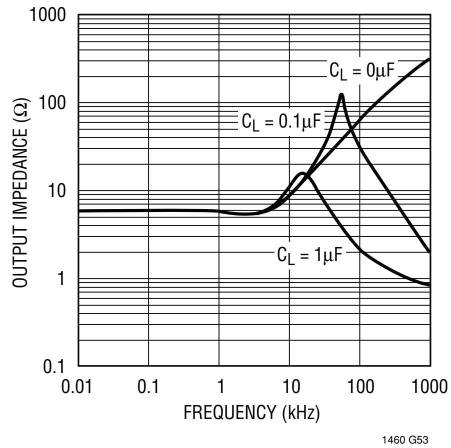
TYPICAL PERFORMANCE CHARACTERISTICS

Characteristic curves are similar for all voltage options of the LT1460S3. Curves from the LT1460S3-2.5 and the LT1460S3-10 represent the extremes of the voltage options. Characteristic curves for other output voltages fall between these curves, and can be estimated based on their voltage output.

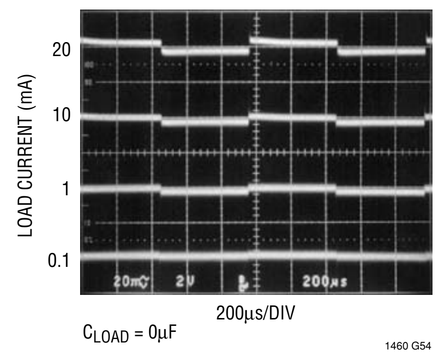
LT1460S3-10V Power Supply Rejection Ratio vs Frequency



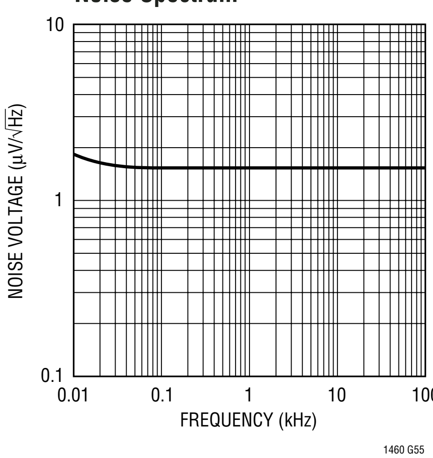
LT1460S3-10V Output Impedance vs Frequency



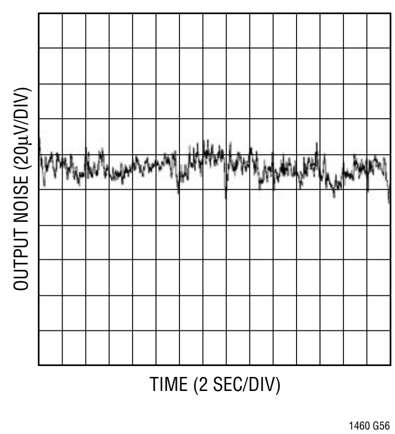
LT1460S3-10V Transient Response



LT1460S3-10V Output Voltage Noise Spectrum



LT1460S3-10V 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 a few mW, yet the same configuration can deliver 20mA of load current when demanded.

Capacitive Loads

The LT1460 is designed to be stable with capacitive loads. With no capacitive load, the reference is ideal for fast settling, applications where PC board space is a premium, or where available capacitance is limited.

The test circuit for the LT1460-2.5 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 current step with a 0.01µF load capacitor. The ringing can 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 LT1460-2.5 with a

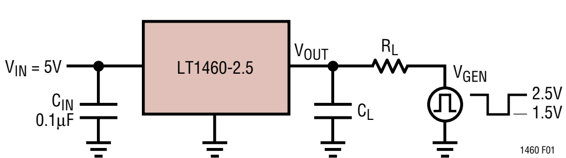


Figure 1. Response Time Test Circuit

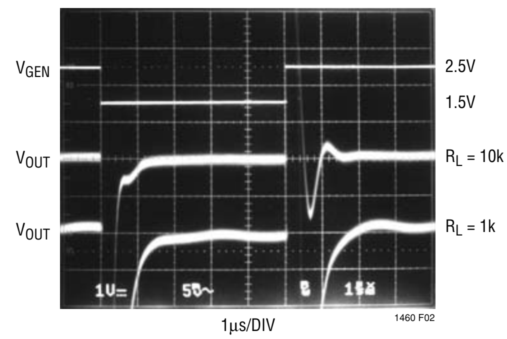


Figure 2. C_L = 0

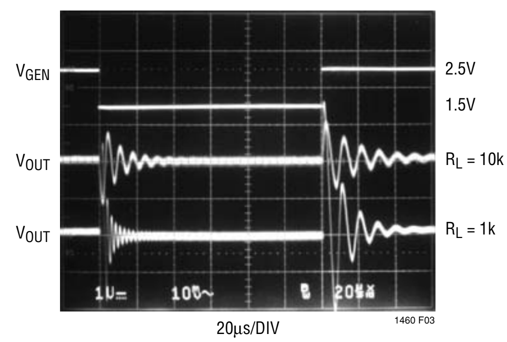


Figure 3. C_L = 0.01µF

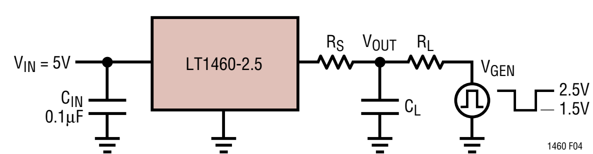


Figure 4. Isolation Resistor Test Circuit

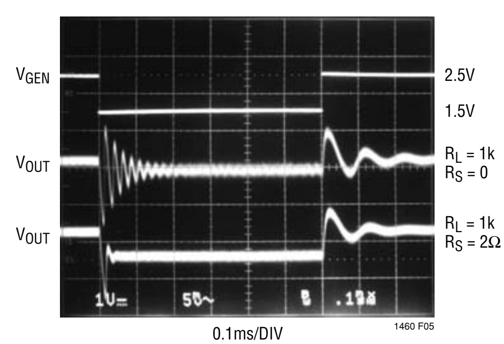


Figure 5. Effect of R_S for C_L = 1µF

APPLICATIONS INFORMATION

R_S = 2Ω and C_L = 1µF. R_S should not be made arbitrarily large because it will limit the load regulation.

Figure 6 to Figure 8 illustrate response in the LT1460-5. The 1V step from 5V to 4V produces a current step of 1mA or 100µA for R_L = 1k or R_L = 10k. Figure 7 shows the response of the reference with no load capacitance.

The reference settles to 5mV (0.1%) in less than 2µs for a 100µA pulse and to 0.1% in 3µs 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 8 shows the response of the reference to a 1mA and 100µA load current step with a 0.01µF load capacitor.

Figure 9 to Figure 11 illustrate response of the LT1460-10. The 1V step from 10V to 9V produces a current step of 1mA or 100µA for R_L = 1k or R_L = 10k. Figure 10 shows the response of the reference with no load capacitance.

The reference settles to 10mV (0.1%) in 0.4µs for a 100µA pulse and to 0.1% in 0.8µs 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 11 shows the response of the reference to a 1mA and 100µA load current step with a 0.01µF load capacitor.

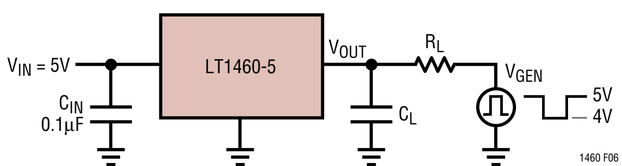


Figure 6. Response Time Test Circuit

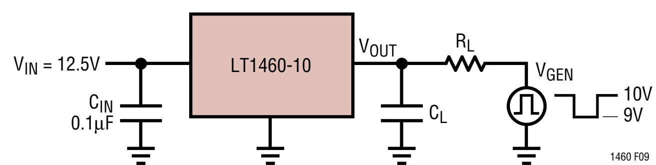


Figure 9. Response Time Test Circuit

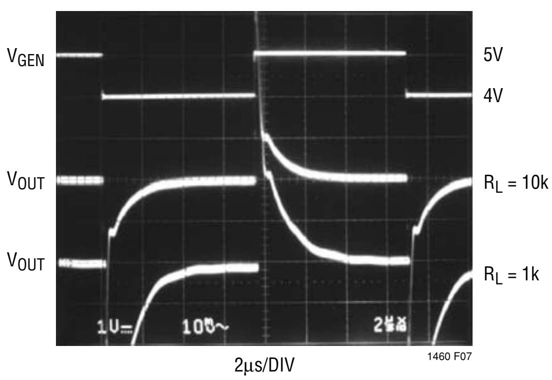


Figure 7. C_L = 0

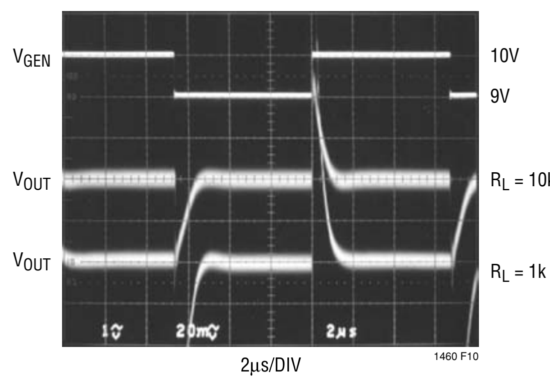


Figure 10. C_L = 0

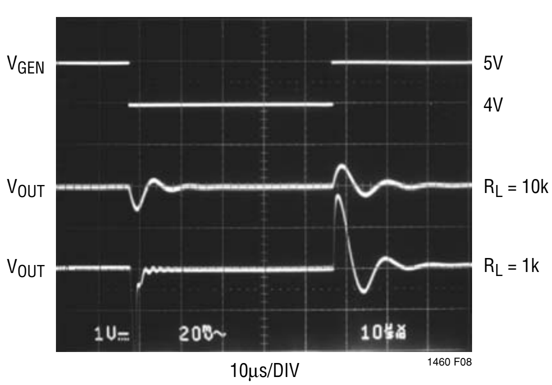


Figure 8. C_L = 0.01µF

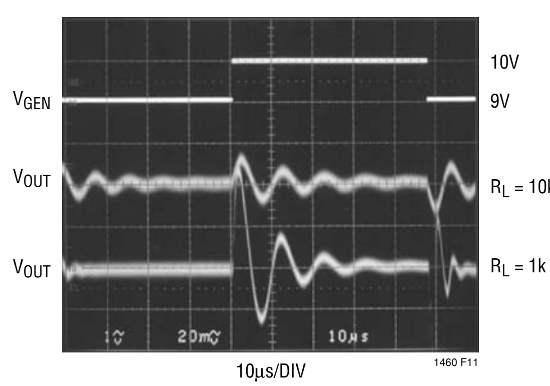


Figure 11. C_L = 0.01µF

APPLICATIONS INFORMATION

Table 1 gives the maximum output capacitance for various load currents and output voltages to avoid instability. Load capacitors with low ESR (effective series resistance) cause more ringing than capacitors with higher ESR such as polarized aluminum or tantalum capacitors.

Table 1. Maximum Output Capacitance

VOLTAGE OPTION	I_{OUT} = 100µA	I_{OUT} = 1mA	I_{OUT} = 10mA	I_{OUT} = 20mA
2.5V	>10µF	>10µF	2µF	0.68µF
3V	>10µF	>10µF	2µF	0.68µF
3.3V	>10µF	>10µF	1µF	0.68µF
5V	>10µF	>10µF	1µF	0.68µF
10V	>10µF	1µF	0.15µF	0.1µF

Long-Term Drift

Long-term drift cannot be extrapolated from accelerated high temperature testing. This erroneous technique gives drift numbers that are wildly optimistic. The only way long-term drift can be determined is to measure it over the time interval of interest. The LT1460S3 long-term drift data was taken on over 100 parts that were soldered into PC boards similar to a "real world" application. The boards were then placed into a constant temperature oven with T_A = 30°C, their outputs were scanned regularly and measured with an 8.5 digit DVM. Figure 12 shows typical long-term drift of the LT1460S3s.

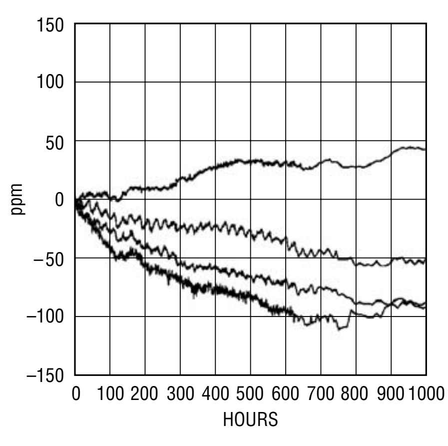


Figure 12. Typical Long-Term Drift

Hysteresis

Hysteresis data shown in Figure 13 and Figure 14 represents the worst-case data taken on parts from 0°C to 70°C and from –40°C to 85°C. The device is capable of dissipating relatively high power, i.e., for the LT1460S3-2.5, PD = 17.5V • 20mA = 350mW. The thermal resistance of the SOT-23 package is 325°C/W and this dissipation causes a 114°C internal rise producing a junction temperature of T_J = 25°C + 114°C = 139°C. This elevated temperature will cause the output to shift due to thermal hysteresis. **For highest performance in precision applications, do not let the LT1460S3's junction temperature exceed 85°C.**

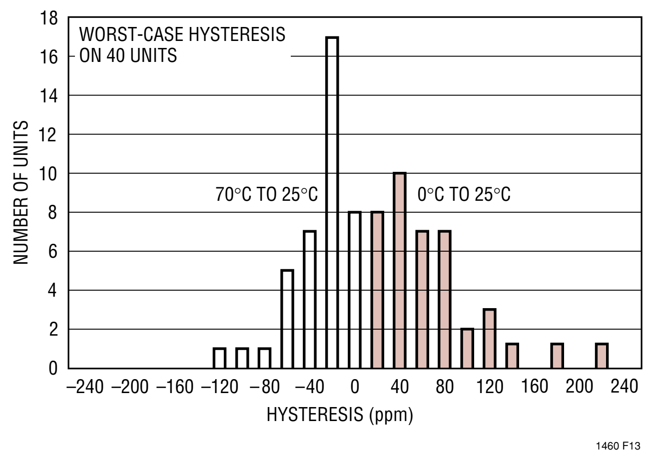


Figure 13. 0°C to 70°C Hysteresis

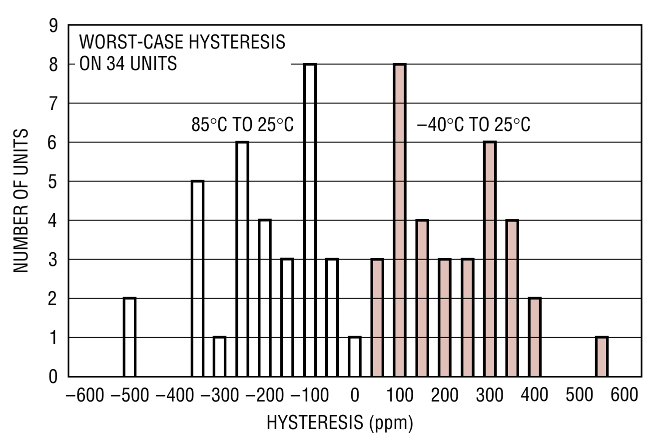


Figure 14. –40°C to 85°C Hysteresis

APPLICATIONS INFORMATION

Input Capacitance

It is recommended that a 0.1μF or larger capacitor be added to the input pin of the LT1460. This can help with stability when large load currents are demanded.

Output Accuracy

Like all references, either series or shunt, the error budget of the LT1460-2.5 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 LT1460-2.5 typically shifts less than 0.01% when soldered into a PCB, so this is also neglected (see PC Board Layout section). The output errors are calculated as follows for a 100μA load and 0°C to 70°C temperature range:

LT1460AC

Initial accuracy = 0.075%

For I_O = 100μA, and using the LT1460-2.5 for calculation,

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

which is 0.035%.

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

$$\Delta V_{OUT} = \left(\frac{10ppm}{°C}\right)(70°C)(2.5V) = 1.75mV$$

which is 0.07%.

Total worst-case output error is:

0.075% + 0.035% + 0.070% = 0.180%.

Table 1 gives worst-case accuracy for the LT1460AC, CC, DC, FC, GC from 0°C to 70°C and the LT1460BI, EI, GI from –40°C to 85°C.

Note that the LT1460-5 and LT1460-10 give identical accuracy as a fraction of their respective output voltages.

PC Board Layout

In 13- to 16-bit systems where initial accuracy and temperature coefficient calibrations have been done, the mechanical and thermal stress on a PC board (in a cardcage for instance) can shift the output voltage and mask the true temperature coefficient of a reference. In addition, the mechanical stress of being soldered into a PC board can cause the output voltage to shift from its ideal value. Surface mount voltage references (MS8 and S8) are the most susceptible to PC board stress because of the small amount of plastic used to hold the lead frame.

A simple way to improve the stress-related shifts is to mount the reference near the short edge of the PC board, or in a corner. The board edge acts as a stress boundary, or a region where the flexure of the board is minimum. The package should always be mounted so that the leads absorb the stress and not the package. The package is generally aligned with the leads parallel to the long side of the PC board as shown in Figure 16a.

A qualitative technique to evaluate the effect of stress on voltage references is to solder the part into a PC board and

Table 1. Worst-Case Output Accuracy Over Temperature

I_{OUT}	LT1460AC	LT1460BI	LT1460CC	LT1460DC	LT1460EI	LT1460FC	LT1460GC	LT1460GI	LT1460HC	LT1460JC	LT1460KC
0	0.145%	0.225%	0.205%	0.240%	0.375%	0.325%	0.425%	0.562%	0.340%	0.540%	0.850%
100μA	0.180%	0.260%	0.240%	0.275%	0.410%	0.360%	0.460%	0.597%	0.380%	0.580%	0.890%
10mA	0.325%	0.405%	0.385%	0.420%	0.555%	0.505%	0.605%	0.742%	0.640%	0.840%	1.15%
20mA	0.425%	N/A	0.485%	0.520%	N/A	0.605%	0.705%	N/A	0.540%	0.740%	1.05%

APPLICATIONS INFORMATION

deform the board a fixed amount as shown in Figure 15. The flexure #1 represents no displacement, flexure #2 is concave movement, flexure #3 is relaxation to no displacement and finally, flexure #4 is a convex movement. This motion is repeated for a number of cycles and the relative output deviation is noted. The result shown in Figure 16a is for two LT1460S8-2.5s mounted vertically and Figure 16b is for two LT1460S8-2.5s mounted horizontally. The parts oriented in Figure 16a impart less stress into the package because stress is absorbed in the leads. Figures 16a and 16b show the deviation to be between 125μV and 250μV and implies a 50ppm and 100ppm change respectively. This corresponds to a 13- to 14-bit system and is not a problem for most 10- to 12-bit systems unless the system has a calibration. In this case, as with temperature hysteresis, this low level can be important and even more careful techniques are required.

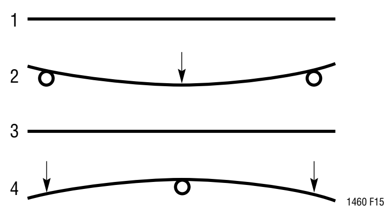


Figure 15. Flexure Numbers

The most effective technique to improve PC board stress is to cut slots in the board around the reference to serve as a strain relief. These slots can be cut on three sides of the reference and the leads can exit on the fourth side. This "tongue" of PC board material can be oriented in the long direction of the board to further reduce stress transferred to the reference.

The results of slotting the PC boards of Figures 16a and 16b are shown in Figures 17a and 17b. In this example the slots can improve the output shift from about 100ppm to nearly zero.

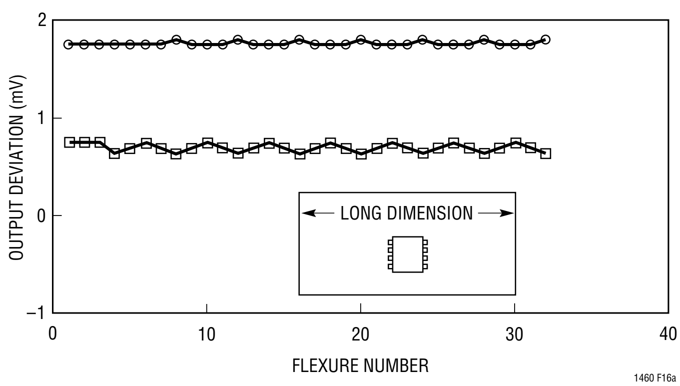


Figure 16a. Two Typical LT1460S8-2.5s, Vertical Orientation Without Slots

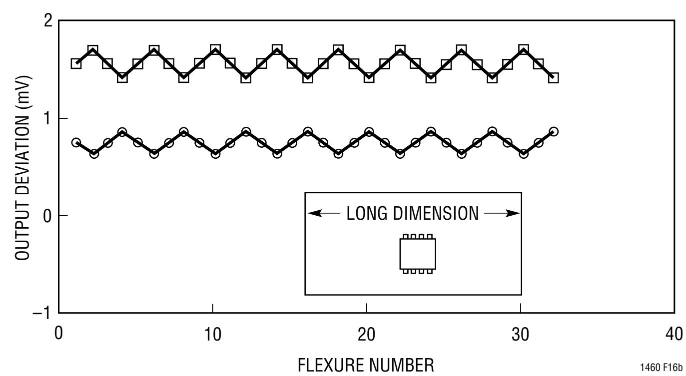


Figure 16b. Two Typical LT1460S8-2.5s, Horizontal Orientation Without Slots

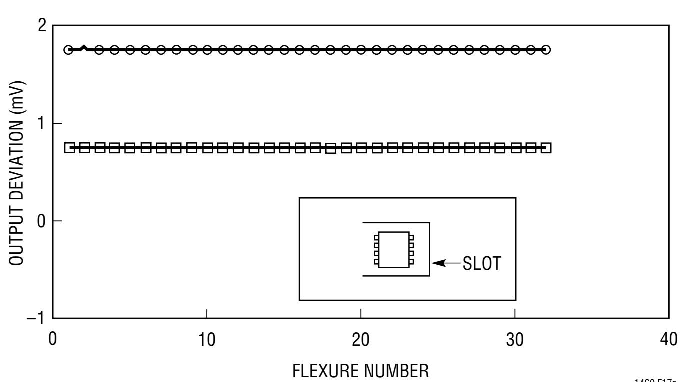


Figure 17a. Same Two LT1460S8-2.5s in Figure 16a, but with Slots

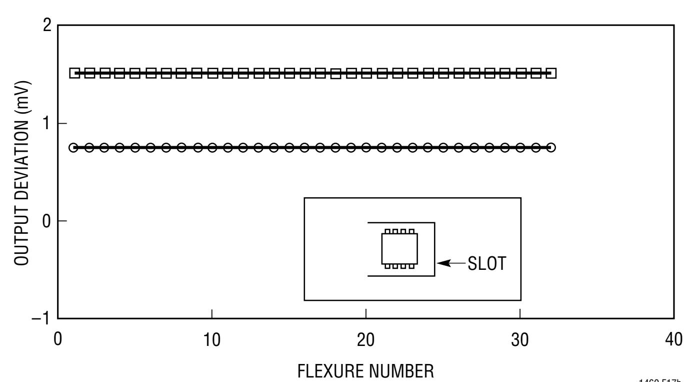
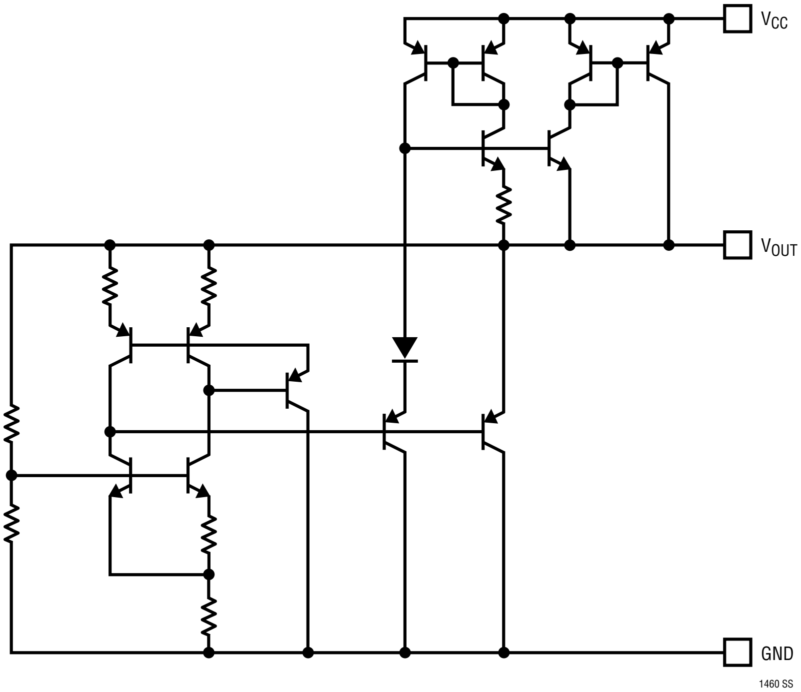


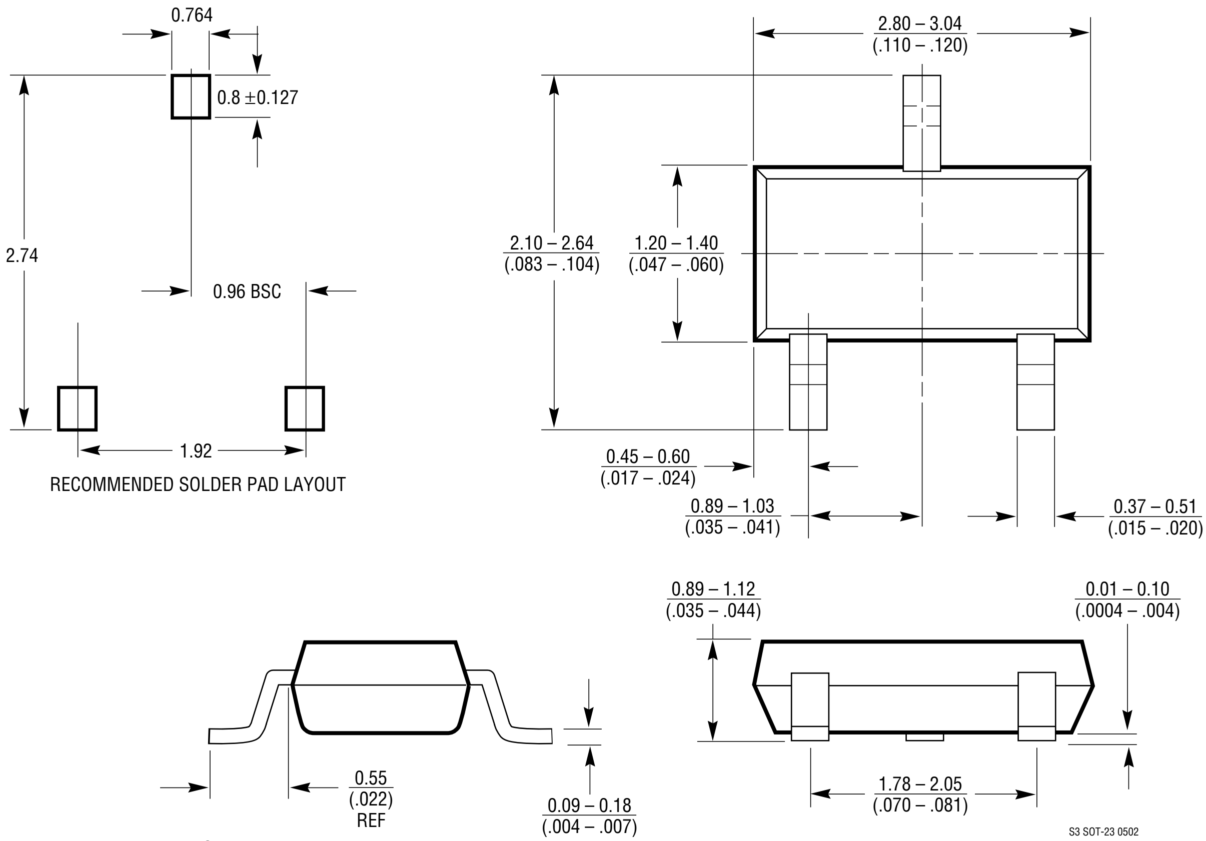
Figure 17b. Same Two LT1460S8-2.5s in Figure 16b, but with Slots

SIMPLIFIED SCHEMATIC



PACKAGE DESCRIPTION

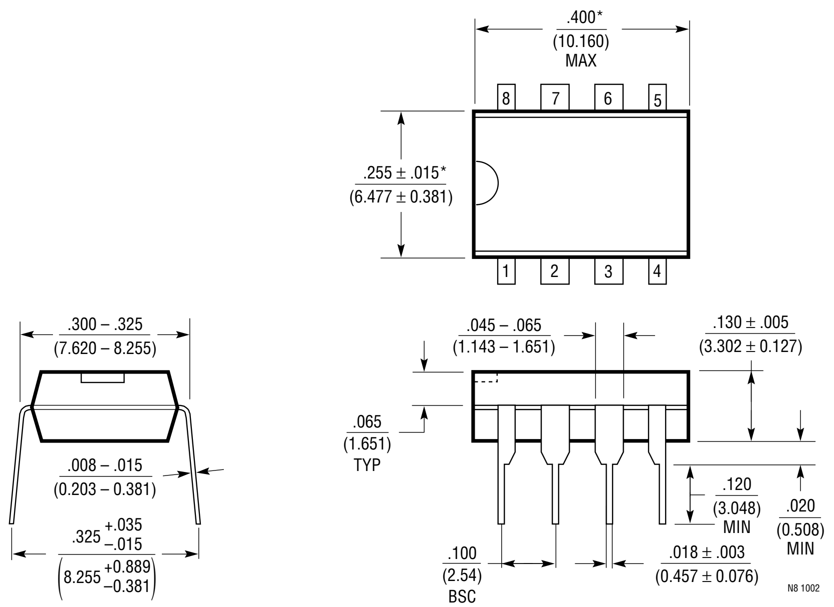
S3 Package
3-Lead Plastic SOT-23
(Reference LTC DWG # 05-08-1631)



NOTE:
1. CONTROLLING DIMENSION: MILLIMETERS
2. DIMENSIONS ARE IN $\frac{\text{MILLIMETERS}}{\text{(INCHES)}}$
3. DRAWING NOT TO SCALE
4. DIMENSIONS ARE INCLUSIVE OF PLATING
5. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
6. MOLD FLASH SHALL NOT EXCEED .254mm
7. PACKAGE JEDEC REFERENCE IS TO-236 VARIATION AB

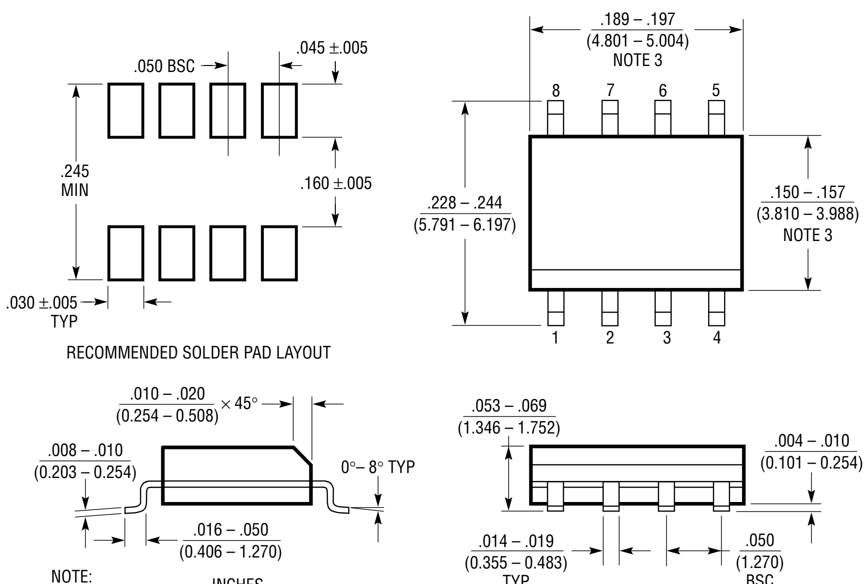
PACKAGE DESCRIPTION

N8 Package
8-Lead PDIP (Narrow .300 Inch)
(Reference LTC DWG # 05-08-1510)



NOTE:
1. DIMENSIONS ARE $\frac{\text{INCHES}}{\text{MILLIMETERS}}$
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

S8 Package
8-Lead Plastic Small Outline (Narrow .150 Inch)
(Reference LTC DWG # 05-08-1610)



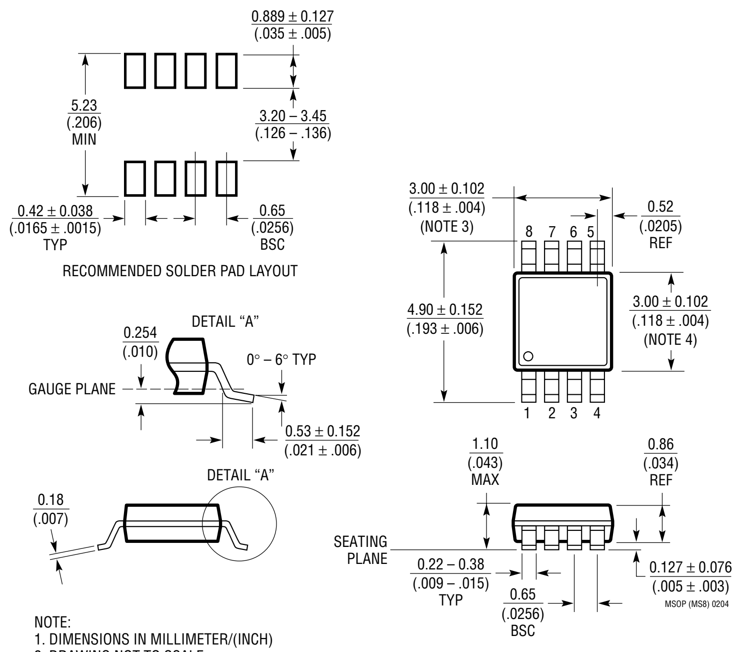
NOTE:
1. DIMENSIONS IN $\frac{\text{INCHES}}{\text{(MILLIMETERS)}}$
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

SO8 0303

1460f

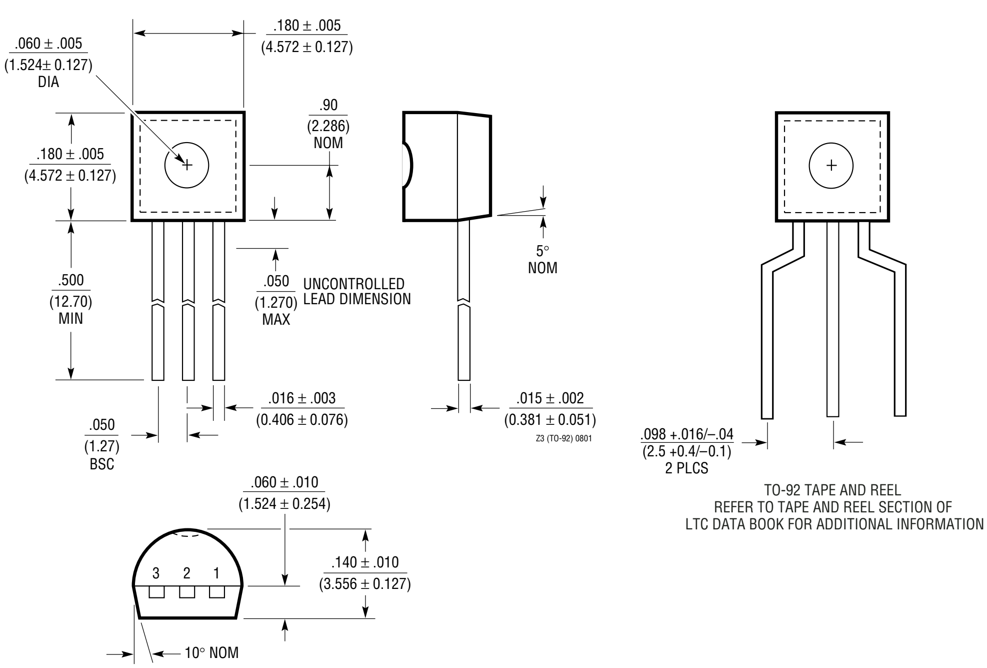
PACKAGE DESCRIPTION

MS8 Package
8-Lead Plastic MSOP
(Reference LTC DWG # 05-08-1660)



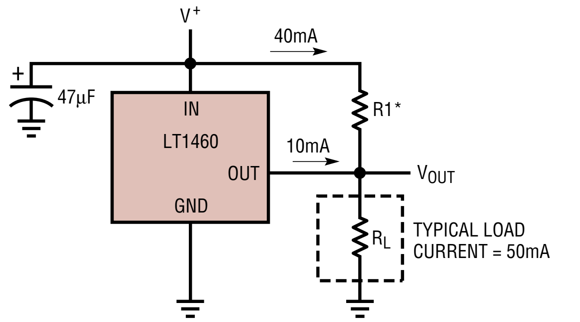
NOTE:
1. DIMENSIONS IN MILLIMETER/(INCH)
2. DRAWING NOT TO SCALE
3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS. INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
5. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.102mm (.004") MAX

Z Package
3-Lead Plastic TO-92 (Similar to TO-226)
(Reference LTC DWG # 05-08-1410)



TYPICAL APPLICATIONS

Handling Higher Load Currents

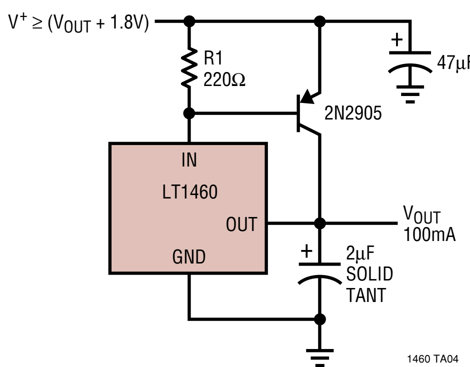


*SELECT R1 TO DELIVER 80% OF TYPICAL LOAD CURRENT. LT1460 WILL THEN SOURCE AS NECESSARY TO MAINTAIN PROPER OUTPUT. DO NOT REMOVE LOAD AS OUTPUT WILL BE DRIVEN UNREGULATED HIGH. LINE REGULATION IS DEGRADED IN THIS APPLICATION

$$R1 = \frac{V^+ - V_{OUT}}{40mA}$$

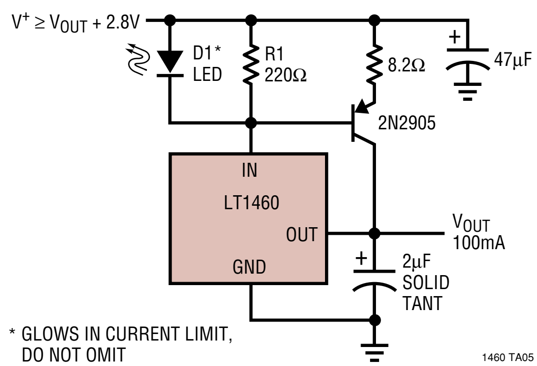
1460 TA03

Boosted Output Current with No Current Limit



1460 TA04

Boosted Output Current with Current Limit



* GLOWS IN CURRENT LIMIT, DO NOT OMIT

1460 TA05

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1019	Precision Bandgap Reference	0.05% Max, 5ppm/°C Max
LT1027	Precision 5V Reference	0.02%, 2ppm/°C Max
LT1236	Precision Low Noise Reference	0.05% Max, 5ppm/°C Max, SO Package
LT1461	Micropower Precision Low Dropout	0.04% Max, 3ppm/°C Max, 50mA Output Current
LT1634	Micropower Precision Shunt Reference 1.25V, 2.5V Output	0.05%, 25ppm/°C Max
LT1790	Micropower Precision Series References	0.05% Max, 10ppm/°C Max, 60µA Supply, SOT23 Package
LTC®1798	Micropower Low Dropout Reference, Fixed or Adjustable	0.15% Max, 40ppm/°C, 6.5µA Max Supply Current
LT6660	Tiny Micropower Precision Series References	0.075% Max, 10ppm/°C Max, 20mA Output, 2mm × 2mm DFN Package

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