

1ppm/°C, 5.0V, Precision Low-Power FGA™ Voltage Reference

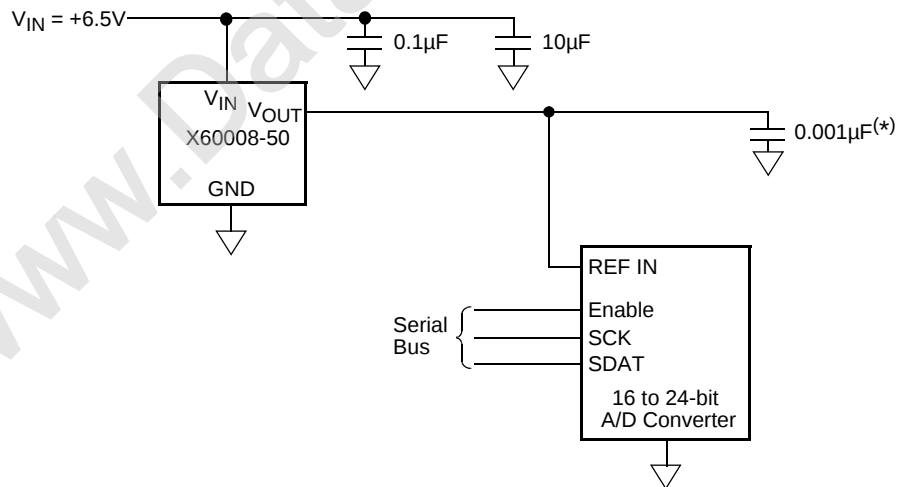
FEATURES

- Ultra-Low Temperature Coefficient: 1ppm/°C
- Absolute Initial Accuracy: $\pm 0.5\text{mV}$
- 10ppm Thermal Hysteresis
- Ultra-Low Supply Current : 800nA maximum
- Long Term Stability: 10ppm/1,000Hrs
- 10mA Source & Sink Current
- 80 mA Short Circuit Current Continuous
- ESD: 5kV (Human Body Model), 500V (Machine Model)
- Standard SOIC-8 Package
- Temp. Range: -40°C to $+85^{\circ}\text{C}$

APPLICATIONS

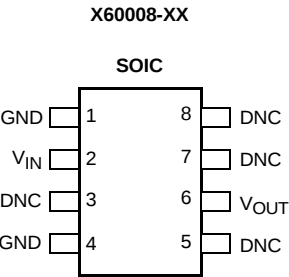
- High Resolution A/Ds & D/As
- High-Accuracy Reference Standard
- Precision Regulators
- Precision Current Sources
- Smart sensors
- Digital Meters
- ATE Equipment
- V-F Converters
- Strain Gage Bridges
- Calibration Systems
- Precision Oscillators
- Threshold Detectors
- Process Control
- Battery Management Systems
- Servo Systems

TYPICAL APPLICATION



(*)Also see Figure 3 in Applications Information

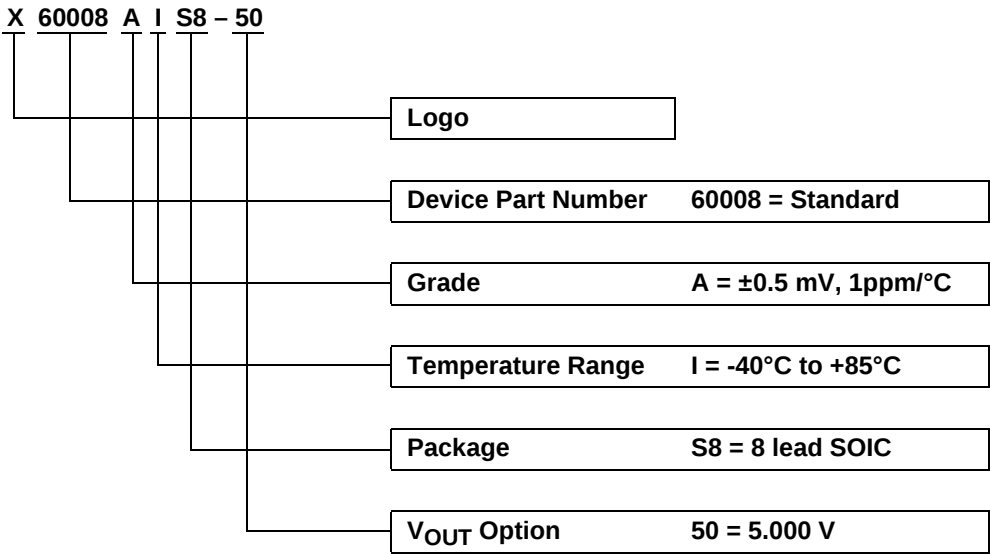
PACKAGE DIAGRAM



PIN CONFIGURATIONS

Pin Name	Description
GND	Ground Connection
V _{IN}	Power Supply Input Connection
V _{OUT}	Voltage Reference Output Connection
DNC	Do Not Connect; Internal Connection – Must Be Left Floating

ORDERING INFORMATION



ABSOLUTE MAXIMUM RATINGS

Storage Temperature Range..... -65°C to +125°C
 Voltage on any Pin Referred to
 Ground -0.5V to +10V
 Lead Temperature
 (soldering, 10 seconds)..... +225°C

RECOMMENDED OPERATING CONDITIONS

Temperature	Min.	Max.
Industrial	-40°C	+85°C

COMMENT

Absolute Maximum Ratings indicate limits beyond which permanent damage to the device and impaired reliability may occur. These are stress ratings provided for information only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification are not implied.

For guaranteed specifications and test conditions, see Electrical Characteristics.

The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

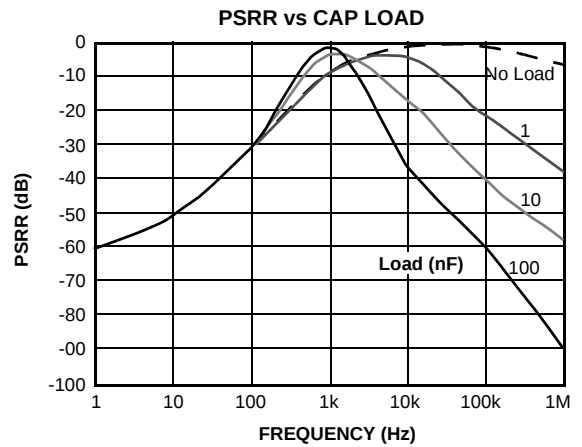
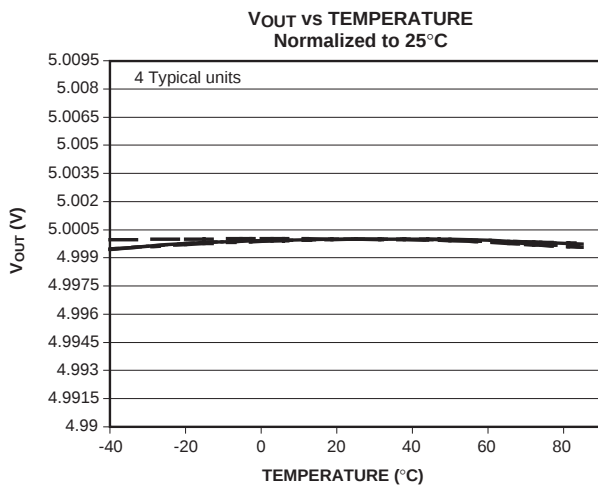
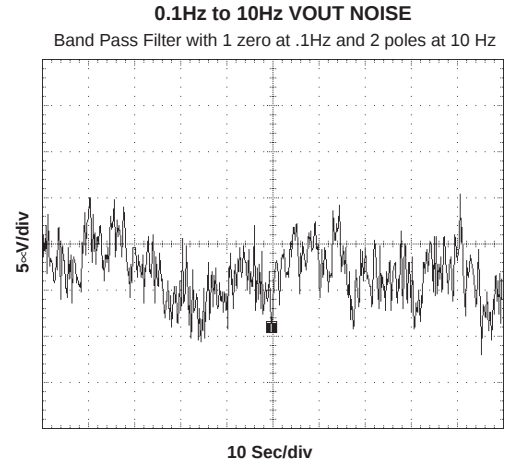
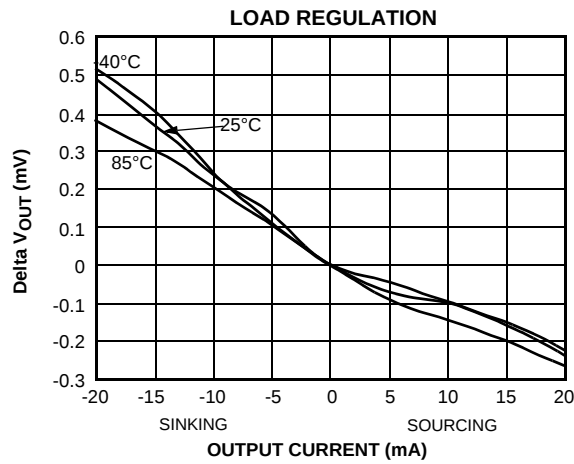
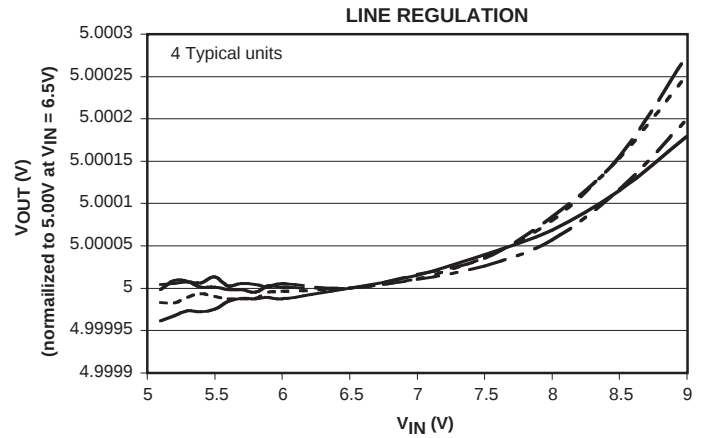
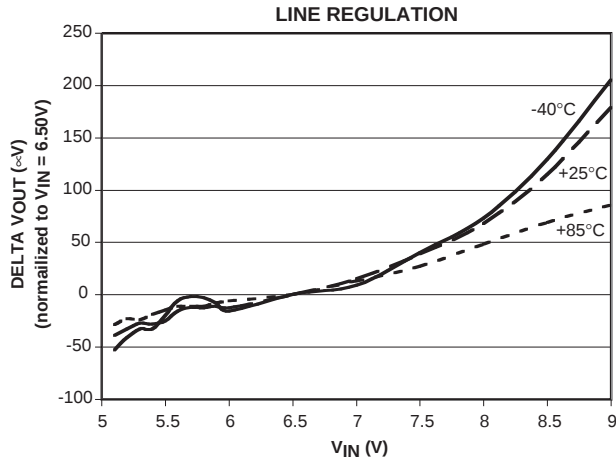
ELECTRICAL CHARACTERISTICS (Operating Conditions: $V_{IN} = +6.5V$, $I_{OUT} = 0mA$, $T_A = -40$ to $+85^\circ C$ unless otherwise noted).

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{OUT}	Output Voltage			5.000		V
V_{OA}	V_{OUT} Accuracy	$T_A = 25^\circ C$	-0.5		+0.5	mV
I_{IN}	Supply Current			500	800	nA
V_{IN}	Input Voltage Range		5.1		9.0	V
TC V_{OUT}	Output Voltage Temperature Coefficient	$-40^\circ C \leq T_A \leq +85^\circ C$ (note:1)		0.5	1.0	ppm/ $^\circ C$
$\Delta V_{OUT}/\Delta V_{IN}$	Line Regulation	$+5.5V \leq V_{IN} \leq +8.0V$			100	$\mu V/V$
$\Delta V_{OUT}/\Delta V_{IN}$	Line Regulation	$+5.5V \leq V_{IN} \leq +8.0V$			20	ppm/V
$\Delta V_{OUT}/\Delta I_{OUT}$	Load Regulation	Sourcing: $0mA \leq I_{OUT} \leq 10mA$ Sinking: $-10mA \leq I_{OUT} \leq 0mA$		10 20	50 100	$\mu V/mA$
$\Delta V_{OUT}/\Delta t$	Long Term Stability	$T_A = 25^\circ C$		10		ppm/ 1,000Hrs
$\Delta V_{OUT}/\Delta T_A$	Thermal Hysteresis	$\Delta T_A = 25^\circ C$ (note: 2)		10		ppm
$\Delta V_{OUT}/\Delta T_A$	Thermal Hysteresis	$\Delta T_A = 125^\circ C$ (note: 3)		50		ppm
I_{SC}	Short Circuit Current	$T_A = 25^\circ C$ (note: 4)		50	80	mA
V_N	V_{OUT} Noise	$0.1Hz \leq f \leq 10Hz$		30		$\mu Vp-p$

- Note:
1. Over the specified temperature range. Temperature coefficient is measured by the box method whereby the change in V_{OUT} is divided by the temperature range; in this case, $-40^\circ C$ to $+85^\circ C = 125^\circ C$.
 2. Measured change in V_{OUT} before and after changing temp by $25^\circ C$.
 3. Thermal Hysteresis is the change in V_{OUT} created by package stress @ $T_A = 25^\circ C$ after temperature cycling. V_{OUT} is read initially at $T_A = 25^\circ C$; the X60008 is then cycled between Hot ($85^\circ C$) and Cold ($-40^\circ C$) before a second V_{OUT} measurement is taken at $25^\circ C$. The deviation between the initial V_{OUT} reading and the second V_{OUT} reading is then expressed in ppm.
 4. Guaranteed by Device Characterization.

TYPICAL PERFORMANCE CHARACTERISTIC CURVES

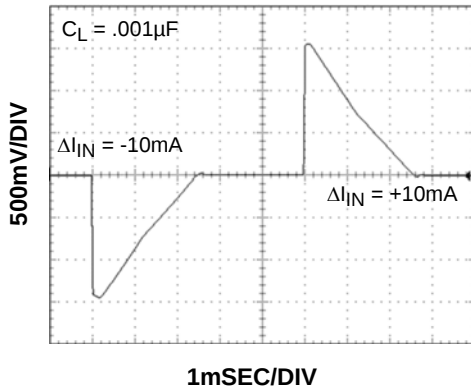
($V_{IN} = 6.5V$, $I_{OUT} = 0mA$, $T_A = 25^\circ C$ unless otherwise specified)



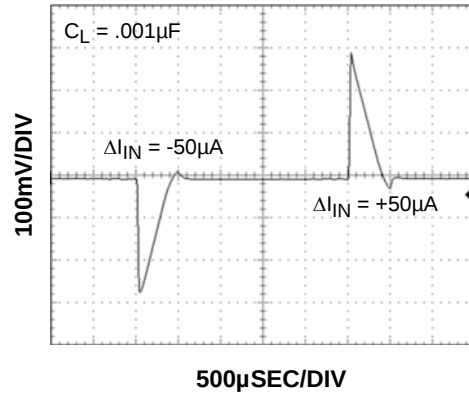
TYPICAL PERFORMANCE CHARACTERISTIC CURVES

($V_{IN} = 6.5V$, $I_{OUT} = 0mA$, $T_A = 25^\circ C$ unless otherwise specified)

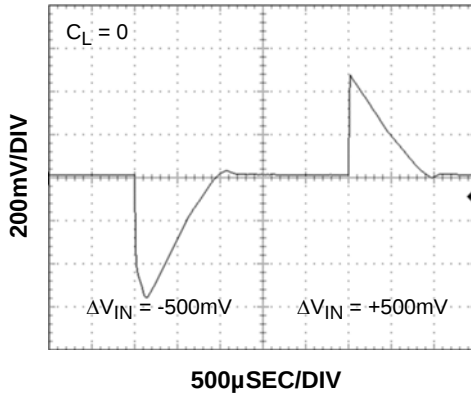
10mA LOAD TRANSIENT RESPONSE



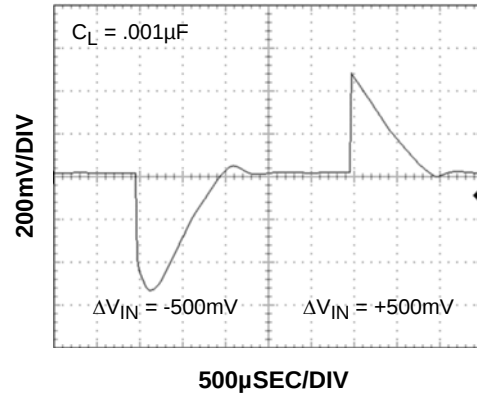
50μA LOAD TRANSIENT RESPONSE



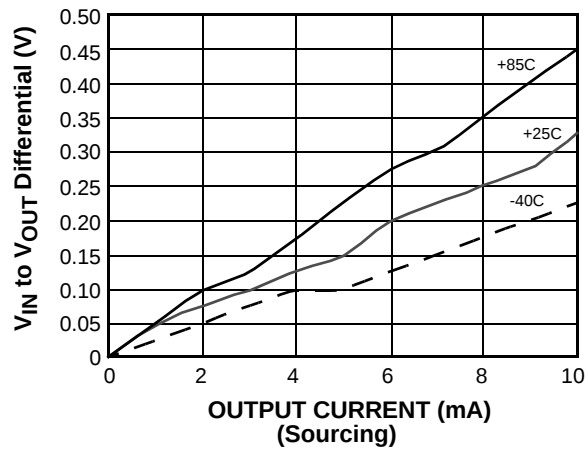
LINE TRANSIENT RESPONSE



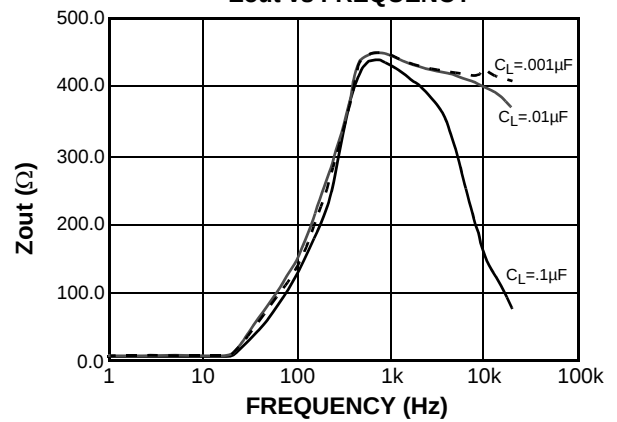
LINE TRANSIENT RESPONSE



MINIMUM V_{IN} to V_{OUT} DIFFERENTIAL vs. OUTPUT CURRENT

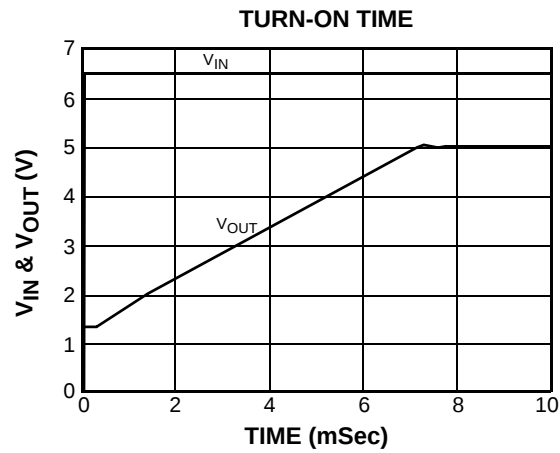
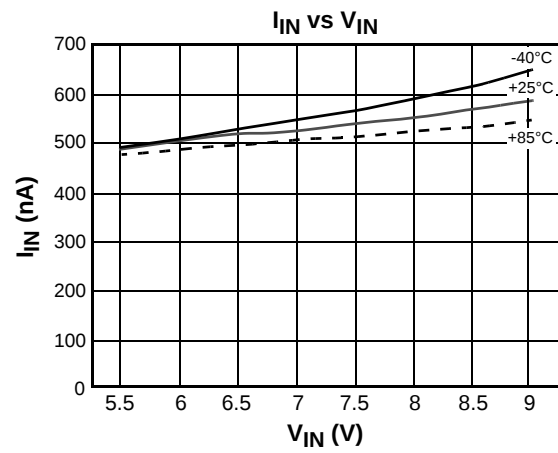
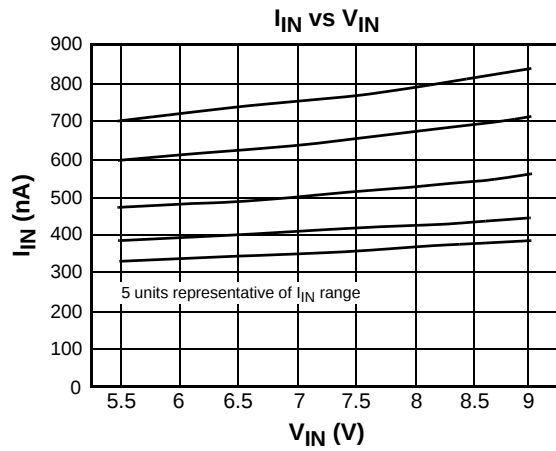


Zout vs FREQUENCY



TYPICAL PERFORMANCE CHARACTERISTIC CURVES

($V_{IN} = 6.5V$, $I_{OUT} = 0mA$, $T_A = 25^\circ C$ unless otherwise specified)



APPLICATIONS INFORMATION

FGA Technology

The X60008 series of voltage references use the floating gate technology to create references with very low drift and supply current. Essentially the charge stored on a floating gate cell is set precisely in manufacturing. The reference voltage output itself is a buffered version of the floating gate voltage. The resulting reference device has excellent characteristics which are unique in the industry: very low temperature drift, high initial accuracy, and almost zero supply current. Also, the reference voltage itself is not limited by voltage bandgaps or zener settings, so a wide range of reference voltages can be programmed (standard voltage settings are provided, but customer-specific voltages are available).

The process used for these reference devices is a floating gate CMOS process, and the amplifier circuitry uses CMOS transistors for amplifier and output transistor circuitry. While providing excellent accuracy, there are limitations in output noise level and load regulation due to the MOS device characteristics. These limitations are addressed with circuit techniques discussed in other sections.

Nanopower Operation

Reference devices achieve their highest accuracy when powered up continuously, and after initial stabilization has taken place. This drift can be eliminated by leaving the power-on continuously.

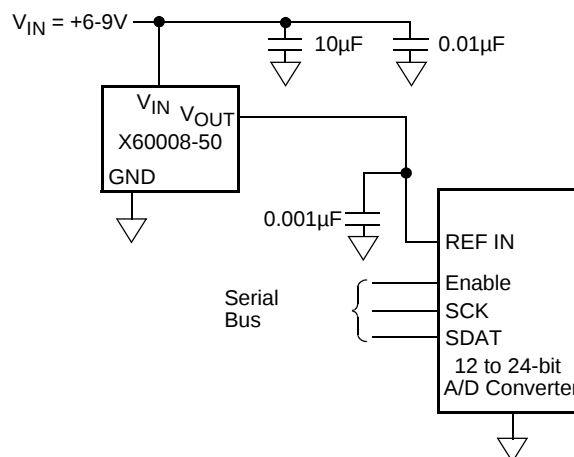
The X60008 is the first high precision voltage reference with ultra low power consumption that makes it practical to leave power-on continuously in battery operated circuits. The X60008 consumes extremely low supply current due to the proprietary FGA technology. Supply current at room temperature is typically 500nA which is 1 to 2 orders of magnitude lower than competitive devices. Application circuits using battery power will benefit greatly from having an accurate, stable reference which essentially presents no load to the battery.

In particular, battery powered data converter circuits that would normally require the entire circuit to be disabled when not in use can remain powered up between conversions as shown in figure 1. Data acquisition circuits providing 12 to 24 bits of accuracy can operate with the reference device continuously biased with no power penalty, providing the highest accuracy and lowest possible long term drift.

Other reference devices consuming higher supply currents will need to be disabled in between conversions to conserve battery capacity. Absolute accuracy will

suffer as the device is biased and requires time to settle to its final value, or, may not actually settle to a final value as power-on time may be short.

Figure 1.



Board mounting Considerations

For applications requiring the highest accuracy, board mounting location should be reviewed. Placing the device in areas subject to slight twisting can cause degradation of the accuracy of the reference voltage due to die stresses. It is normally best to place the device near the edge of a board, or the shortest side, as the axis of bending is most limited at that location. Obviously mounting the device on flexprint or extremely thin PC material will likewise cause loss of reference accuracy.

Noise Performance and Reduction:

The output noise voltage in a 0.1Hz to 10Hz bandwidth is typically 30 μ Vp-p. This is shown in the plot in the Typical Performance Curves. The noise measurement is made with a bandpass filter made of a 1 pole high-pass filter with a corner frequency at .1Hz and a 2-pole low-pass filter with a corner frequency at 12.6Hz to create a filter with a 9.9Hz bandwidth. Noise in the 10KHz to 1MHz bandwidth is approximately 400 μ Vp-p with no capacitance on the output, as shown in Fig. 2 below. These noise measurements are made with a 2 decade bandpass filter made of a 1 pole high-pass filter with a corner frequency at 1/10 of the center frequency and 1-pole low-pass filter with a corner frequency at 10 times the center frequency. Figure 2 also shows the noise in the 10KHz to 1MHz band can be reduced to about 50 μ Vp-p using a .001 μ F capacitor on the output. Noise in the 1KHz to 100KHz band can be further reduced using a 0.1 μ F capacitor on the output, but noise in the 1Hz to 100Hz band increases due to instability of the very low power amplifier with a 0.1 μ F capacitance load. For

load capacitances above $.001\mu\text{F}$ the noise reduction network shown in fig. 3 is recommended. This network reduces noise significantly over the full bandwidth. As shown in fig. 2, noise is reduced to less than $40\mu\text{Vp-p}$ from 1Hz to 1MHz using this network with a $.01\mu\text{F}$ capacitor and a $2\text{k}\Omega$ resistor in series with a $10\mu\text{F}$ capacitor.

Figure 2.

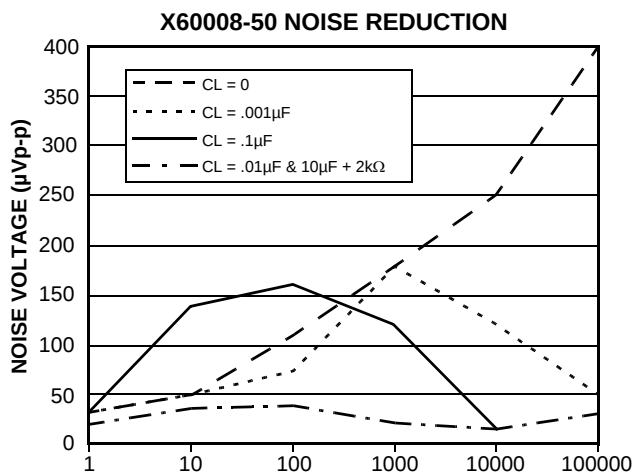
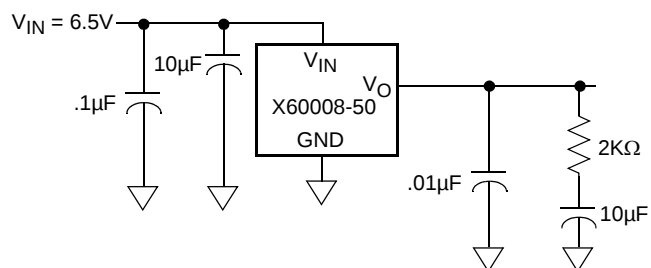


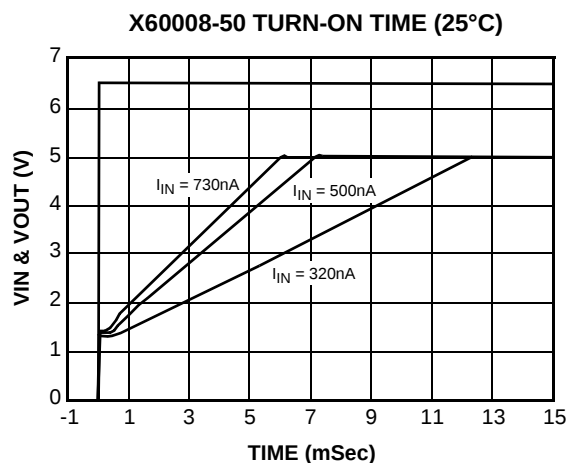
Figure 3.



Turn-On Time

The X60008 devices have ultra-low supply current and thus the time to bias up internal circuitry to final values will be longer than with higher power references. Normal turn-on time is typically 7ms. This is shown in the graph, Figure 4. Since devices can vary in supply current down to 300nA , turn-on time can last up to about 12ms. Care should be taken in system design to include this delay before measurements or conversions are started.

Figure 4.

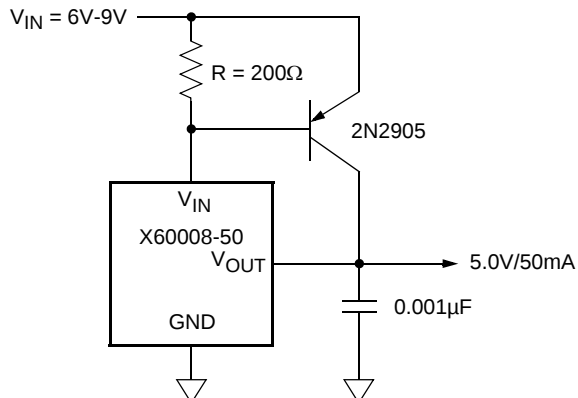


Temperature Coefficient

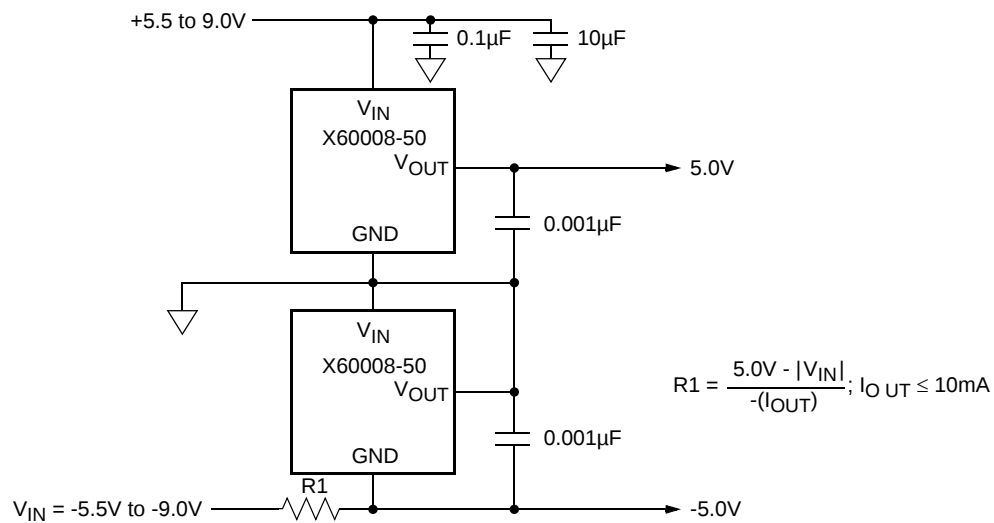
The limits stated for temperature coefficient (tempco) are governed by the method of measurement. The overwhelming standard for specifying the temperature drift of a reference is to measure the reference voltage at two temperatures, take the total variation, $(V_{\text{HIGH}} - V_{\text{LOW}})$, and divide by the temperature extremes of measurement $(T_{\text{HIGH}} - T_{\text{LOW}})$. The result is divided by the nominal reference voltage (at $T = 25^\circ\text{C}$) and multiplied by 10^6 to yield $\text{ppm}/^\circ\text{C}$. This is the "Box" method for determining temperature coefficient.

TYPICAL APPLICATION CIRCUITS

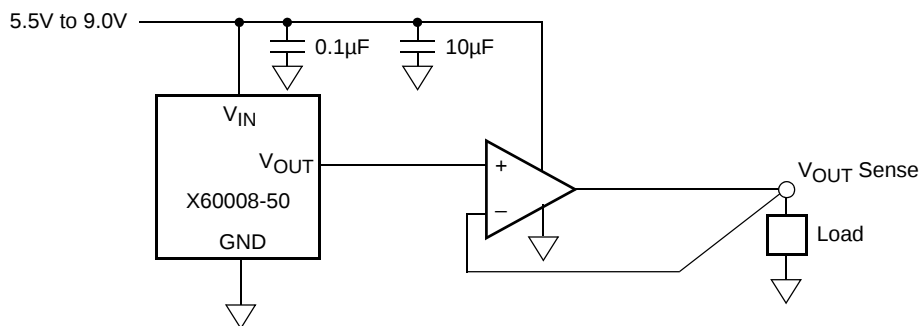
Precision 5V, 50mA Reference.



±5.0V Dual Output, High Accuracy Reference

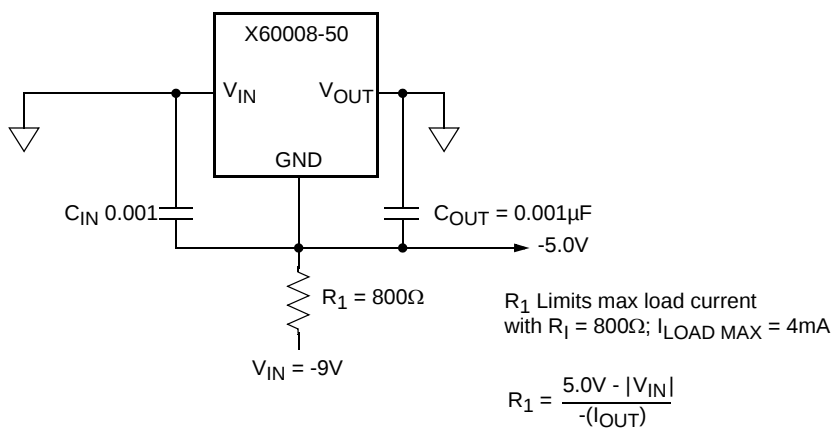


Kelvin Sensed Load

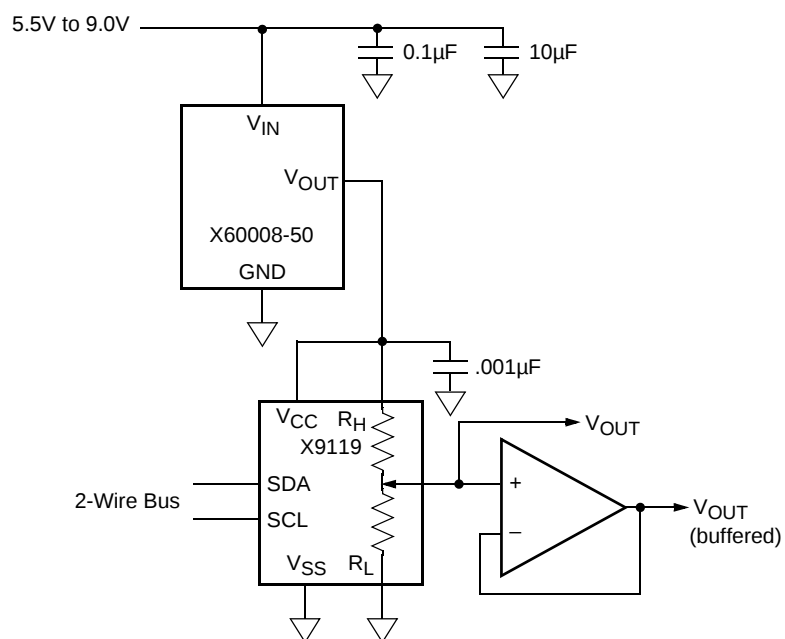


TYPICAL APPLICATION CIRCUITS

Negative Voltage Reference

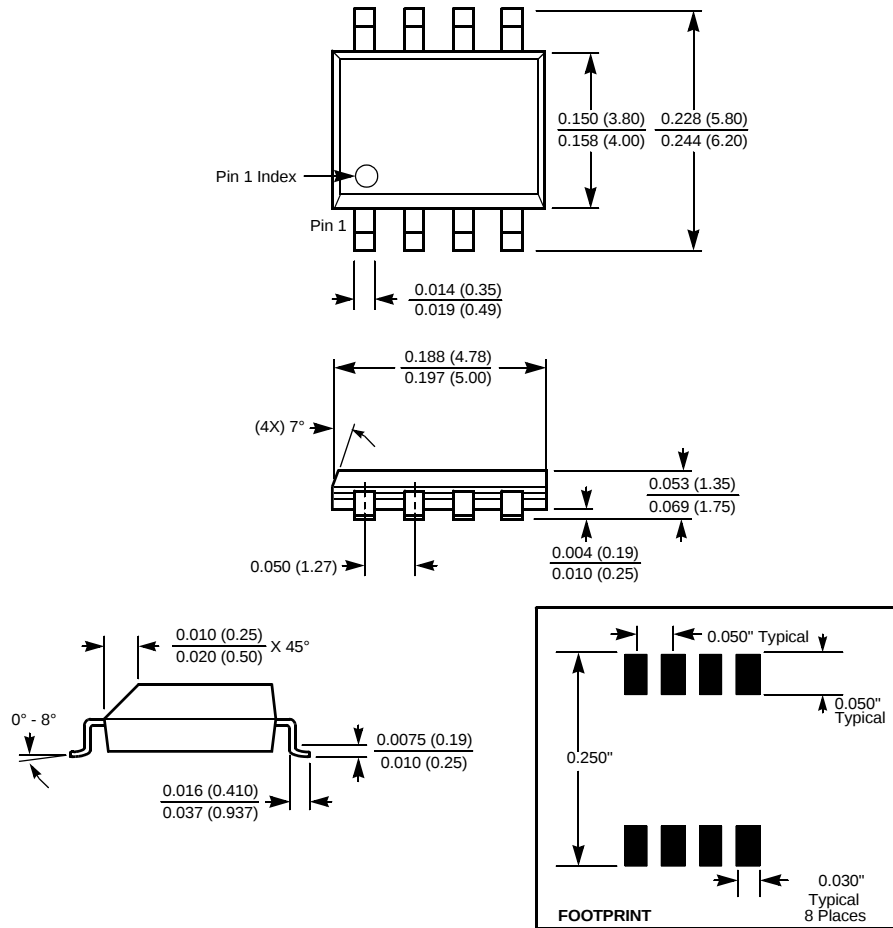


5V Full Scale Low-Drift 10-bit Adjustable Voltage Source



PACKAGING INFORMATION

8-Lead Plastic, SOIC, Package Code S8



NOTE: ALL DIMENSIONS IN INCHES (IN PARENTHESES IN MILLIMETERS)

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