13-1395; Rev 1; 4/99

Low-Cost, Low-Power, Low-Dropout, SOT23-3 Voltage References

General Description

The MAX6001–MAX6005 family of SOT23, low-cost series voltage references meets the cost advantage of shunt references and offers the power-saving advantage of series references, which traditionally cost more. Unlike conventional shunt-mode (two-terminal) references that must be biased at the load current and require an external resistor, these devices eliminate the need for an external resistor and offer a supply current that is virtually independent of the supply voltage.

These micropower, low-dropout, low-cost devices are ideal for high-volume, cost-sensitive 3V and 5V battery-operated systems with wide variations in supply voltage that require very low power dissipation. Additionally, these devices are internally compensated and do not require an external compensation capacitor, saving valuable board area in space-critical applications.

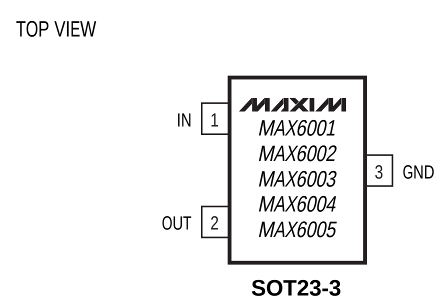
Applications

- Portable/Battery-Powered Equipment
- Notebook Computers
- PDAs, GPSs, and DMMs
- Cellular Phones
- Pagers
- Hard-Disk Drives

Selector Guide

PART	OUTPUT VOLTAGE (V)	INPUT VOLTAGE (V)
MAX6001	1.250	2.5 to 12.6
MAX6002	2.500	(V_{OUT} + 200mV) to 12.6
MAX6003	3.000	(V_{OUT} + 200mV) to 12.6
MAX6004	4.096	(V_{OUT} + 200mV) to 12.6
MAX6005	5.000	(V_{OUT} + 200mV) to 12.6

Pin Configuration



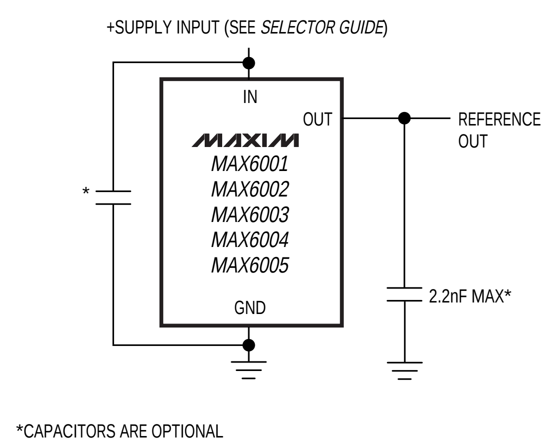
Features

- ♦ 1% max Initial Accuracy
- ♦ 100ppm/°C max Temperature Coefficient
- ♦ 45µA max Quiescent Supply Current
- ♦ 0.8µA/V Supply Current Variation with V_{IN}
- ♦ ±400µA Output Source and Sink Current
- ♦ 100mV Dropout at 400µA Load Current
- ♦ 0.12µV/µA Load Regulation
- ♦ 8µV/V Line Regulation
- ♦ Stable with C_{LOAD} = 0 to 2.2nF

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	SOT TOP MARK
MAX6001EUR-T	-40°C to +85°C	3 SOT23-3	FZCW
MAX6002EUR-T	-40°C to +85°C	3 SOT23-3	FZCX
MAX6003EUR-T	-40°C to +85°C	3 SOT23-3	FZDK
MAX6004EUR-T	-40°C to +85°C	3 SOT23-3	FZCY
MAX6005EUR-T	-40°C to +85°C	3 SOT23-3	FZCZ

Typical Operating Circuit



ABSOLUTE MAXIMUM RATINGS

Voltages Referenced to GND
IN ....-0.3V to +13.5V
OUT ....-0.3V to (V_{IN} + 0.3V)
Output Short Circuit to GND or IN (V_{IN} < 6V) ....Continuous
Output Short Circuit to GND or IN (V_{IN} ≥ 6V) 60sec

Continuous Power Dissipation (T_A = +70°C)
SOT23-3 (derate 4.0mW/°C above +70°C)..................320mW
Operating Temperature Range ....-40°C to +85°C
Storage Temperature Range ....-65°C to +150°C
Lead Temperature (soldering, 10sec) ....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—MAX6001

(V_{IN} = +5V, I_{OUT} = 0, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
OUTPUT						
Output Voltage	V_{OUT}	T_A = +25°C	1.237	1.250	1.263	V
Output Voltage Temperature Coefficient (Note 2)	TCV_{OUT}			20	100	ppm/°C
Line Regulation	$\Delta V_{OUT}/\Delta V_{IN}$	2.5V ≤ V_{IN} ≤ 12.6V		8	120	µV/V
Load Regulation	$\Delta V_{OUT}/\Delta I_{OUT}$	Sourcing: 0 ≤ I_{OUT} ≤ 400µA		0.12	0.8	µV/µA
		Sinking: -400µA ≤ I_{OUT} ≤ 0		0.15	1.0	
OUT Short-Circuit Current	I_{SC}	Short to GND		4		mA
		Short to IN		4		
Temperature Hysteresis (Note 3)				130		ppm
Long-Term Stability	ΔV_{OUT}/time	1,000 hours at T_A = +25°C		50		ppm/1,000hrs
DYNAMIC						
Noise Voltage	e_{OUT}	f = 0.1Hz to 10Hz		25		µVp-p
		f = 10Hz to 10kHz		65		$µV_{RMS}$
Ripple Rejection	$\Delta V_{OUT}/\Delta V_{IN}$	V_{IN} = 5V ±100mV, f = 120Hz		86		dB
Turn-On Settling Time	t_R	To V_{OUT} = 0.1% of final value, C_{OUT} = 50pF		30		µs
Capacitive-Load Stability Range	C_{OUT}	(Note 4)	0		2.2	nF
INPUT						
Supply Voltage Range	V_{IN}	Guaranteed by line-regulation test	2.5		12.6	V
Quiescent Supply Current	I_{IN}			27	45	µA
Change in Supply Current	I_{IN}/V_{IN}	2.5V ≤ V_{IN} ≤ 12.6V		0.8	2.6	µA/V

ELECTRICAL CHARACTERISTICS—MAX6002

(V_{IN} = +5V, I_{OUT} = 0, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
OUTPUT						
Output Voltage	V_{OUT}	T_A = +25°C	2.475	2.500	2.525	V
Output Voltage Temperature Coefficient (Note 2)	TCV_{OUT}			20	100	ppm/°C
Line Regulation	$\Delta V_{OUT}/\Delta V_{IN}$	(V_{OUT} + 0.2V) ≤ V_{IN} ≤ 12.6V		15	200	µV/V
Load Regulation	$\Delta V_{OUT}/\Delta I_{OUT}$	Sourcing: 0 ≤ I_{OUT} ≤ 400µA		0.14	0.90	µV/µA
		Sinking: -400µA ≤ I_{OUT} ≤ 0		0.18	1.10	
Dropout Voltage (Note 5)	V_{IN} - V_{OUT}	I_{OUT} = 400µA		100	200	mV
OUT Short-Circuit Current	I_{SC}	Short to GND		4		mA
		Short to IN		4		
Temperature Hysteresis (Note 3)	ΔV_{OUT}/time			130		ppm
Long-Term Stability	ΔV_{OUT}/time	1,000 hours at T_A = +25°C		50		ppm/ 1,000hrs
DYNAMIC						
Noise Voltage	e_{OUT}	f = 0.1Hz to 10Hz		60		µVp-p
		f = 10Hz to 10kHz		125		μV_{RMS}
Ripple Rejection	$\Delta V_{OUT}/\Delta V_{IN}$	V_{IN} = 5V ±100mV, f = 120Hz		82		dB
Turn-On Settling Time	t_R	To V_{OUT} = 0.1% of final value, C_{OUT} = 50pF		85		µs
Capacitive-Load Stability Range	C_{OUT}	(Note 4)	0		2.2	nF
INPUT						
Supply Voltage Range	V_{IN}	Guaranteed by line-regulation test	V_{OUT} + 0.2		12.6	V
Quiescent Supply Current	I_{IN}			27	45	µA
Change in Supply Current	I_{IN}/V_{IN}	(V_{OUT} + 0.2V) ≤ V_{IN} ≤ 12.6V		0.8	2.6	µA/V

ELECTRICAL CHARACTERISTICS—MAX6003

(V_{IN} = +5V, I_{OUT} = 0, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
OUTPUT						
Output Voltage	V_{OUT}	T_A = +25°C	2.97	3.00	3.03	V
Output Voltage Temperature Coefficient (Note 2)	TCV_{OUT}			20	100	ppm/°C
Line Regulation	$\Delta V_{OUT}/\Delta V_{IN}$	(V_{OUT} + 0.2V) ≤ V_{IN} ≤ 12.6V		20	220	µV/V
Load Regulation	$\Delta V_{OUT}/\Delta I_{OUT}$	Sourcing: 0 ≤ I_{OUT} ≤ 400µA		0.14	0.90	µV/µA
		Sinking: -400µA ≤ I_{OUT} ≤ 0		0.18	1.10	
Dropout Voltage (Note 5)	V_{IN} - V_{OUT}	I_{OUT} = 400µA		100	200	mV
OUT Short-Circuit Current	I_{SC}	Short to GND		4		mA
		Short to IN		4		
Temperature Hysteresis (Note 3)	ΔV_{OUT}/ time			130		ppm
Long-Term Stability	ΔV_{OUT}/ time	1,000 hours at T_A = +25°C		50		ppm/ 1,000hrs
DYNAMIC						
Noise Voltage	e_{OUT}	f = 0.1Hz to 10Hz		75		µVp-p
		f = 10Hz to 10kHz		150		$µV_{RMS}$
Ripple Rejection	$\Delta V_{OUT}/\Delta V_{IN}$	V_{IN} = 5V ±100mV, f = 120Hz		80		dB
Turn-On Settling Time	t_R	To V_{OUT} = 0.1% of final value, C_{OUT} = 50pF		100		µs
Capacitive-Load Stability Range	C_{OUT}	(Note 4)	0		2.2	nF
INPUT						
Supply Voltage Range	V_{IN}	Guaranteed by line-regulation test	V_{OUT} + 0.2		12.6	V
Quiescent Supply Current	I_{IN}			27	45	µA
Change in Supply Current	I_{IN}/V_{IN}	(V_{OUT} + 0.2V) ≤ V_{IN} ≤ 12.6V		0.8	2.6	µA/V

ELECTRICAL CHARACTERISTICS—MAX6004

(V_{IN} = +5V, I_{OUT} = 0, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
OUTPUT						
Output Voltage	V_{OUT}	T_A = +25°C	4.055	4.096	4.137	V
Output Voltage Temperature Coefficient (Note 2)	TCV_{OUT}			20	100	ppm/°C
Line Regulation	$\Delta V_{OUT}/\Delta V_{IN}$	(V_{OUT} + 0.2V) ≤ V_{IN} ≤ 12.6V		25	240	µV/V
Load Regulation	$\Delta V_{OUT}/\Delta I_{OUT}$	Sourcing: 0 ≤ I_{OUT} ≤ 400µA		0.15	1.00	µV/µA
		Sinking: -400µA ≤ I_{OUT} ≤ 0		0.20	1.20	
Dropout Voltage (Note 5)	V_{IN} - V_{OUT}	I_{OUT} = 400µA		100	200	mV
OUT Short-Circuit Current	I_{SC}	Short to GND		4		mA
		Short to IN		4		
Temperature Hysteresis (Note 3)	ΔV_{OUT}/time	1,000 hours at T_A = +25°C		130		ppm
Long-Term Stability	ΔV_{OUT}/time	1,000 hours at T_A = +25°C		50		ppm/1,000hrs
DYNAMIC						
Noise Voltage	e_{OUT}	f = 0.1Hz to 10Hz		100		µVp-p
		f = 10Hz to 10kHz		200		$µV_{RMS}$
Ripple Rejection	$\Delta V_{OUT}/\Delta V_{IN}$	V_{IN} = 5V ±100mV, f = 120Hz		77		dB
Turn-On Settling Time	t_R	To V_{OUT} = 0.1% of final value, C_{OUT} = 50pF		160		µs
Capacitive-Load Stability Range	C_{OUT}	(Note 4)	0		2.2	nF
INPUT						
Supply Voltage Range	V_{IN}	Guaranteed by line-regulation test	V_{OUT} + 0.2		12.6	V
Quiescent Supply Current	I_{IN}			27	45	µA
Change in Supply Current	I_{IN}/V_{IN}	(V_{OUT} + 0.2V) ≤ V_{IN} ≤ 12.6V		0.8	2.6	µA/V

ELECTRICAL CHARACTERISTICS—MAX6005

(V_{IN} = +5.5V, I_{OUT} = 0, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

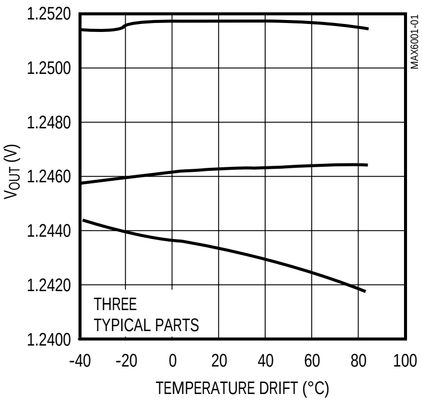
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
OUTPUT						
Output Voltage	V_{OUT}	T_A = +25°C	4.950	5.000	5.050	V
Output Voltage Temperature Coefficient (Note 2)	TCV_{OUT}			20	100	ppm/°C
Line Regulation	$\Delta V_{OUT}/\Delta V_{IN}$	(V_{OUT} + 0.2V) ≤ V_{IN} ≤ 12.6V		25	240	µV/V
Load Regulation	$\Delta V_{OUT}/\Delta I_{OUT}$	Sourcing: 0 ≤ I_{OUT} ≤ 400µA		0.17	1.00	µV/µA
		Sinking: -400µA ≤ I_{OUT} ≤ 0		0.24	1.20	µV/µA
Dropout Voltage (Note 5)	V_{IN} - V_{OUT}	I_{OUT} = 400µA		100	200	mV
OUT Short-Circuit Current	I_{SC}	Short to GND		4		mA
		Short to IN		4		mA
Temperature Hysteresis (Note 3)				130		ppm
Long-Term Stability	ΔV_{OUT}/time	1,000 hours at T_A = +25°C		50		ppm/1,000hrs
DYNAMIC						
Noise Voltage	e_{OUT}	f = 0.1Hz to 10Hz		120		µVp-p
		f =10Hz to 10kHz		240		$µV_{RMS}$
Ripple Rejection	$\Delta V_{OUT}/\Delta V_{IN}$	V_{IN} = 5V ±100mV, f = 120Hz		72		dB
Turn-On Settling Time	t_R	To V_{OUT} = 0.1% of final value, C_{OUT} = 50pF		220		µs
Capacitive-Load Stability Range	C_{OUT}	(Note 4)	0		2.2	nF
INPUT						
Supply Voltage Range	V_{IN}	Guaranteed by line-regulation test	V_{OUT} + 0.2		12.6	V
Quiescent Supply Current	I_{IN}			27	45	µA
Change in Supply Current	I_{IN}/V_{IN}	(V_{OUT} + 0.2V) ≤ V_{IN} ≤ 12.6V		0.8	2.6	µA/V

Note 1: All devices are 100% production tested at T_A = +25°C and are guaranteed by design for T_A = T_{MIN} to T_{MAX}, as specified.
Note 2: Temperature coefficient is measured by the “box” method; i.e., the maximum ΔV_{OUT} is divided by the maximum Δt.
Note 3: Thermal hysteresis is defined as the change in +25°C output voltage before and after cycling the device from T_{MIN} to T_{MAX}.
Note 4: Not production tested. Guaranteed by design.
Note 5: Dropout voltage is the minimum input voltage at which V_{OUT} changes ≤ 0.2% from V_{OUT} at V_{IN} = 5.0V (V_{IN} = 5.5V for MAX6005).

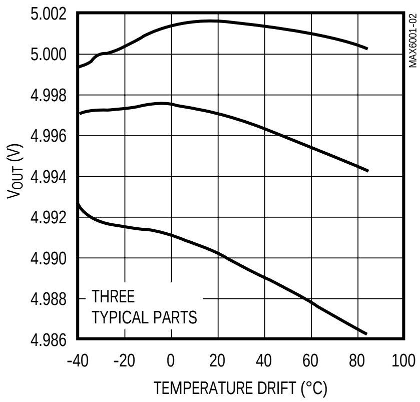
Typical Operating Characteristics

(V_{IN} = +5V for MAX6001–MAX6004, V_{IN} = +5.5V for MAX6005; I_{OUT} = 0; T_A = +25°C; unless otherwise noted.) (Note 6)

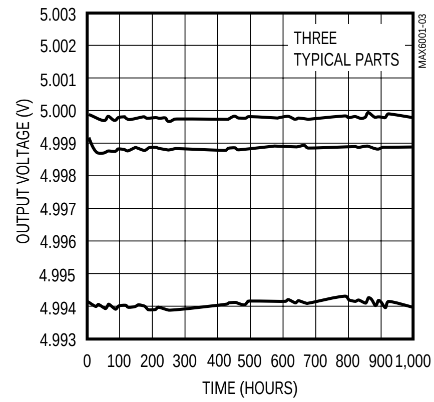
MAX6001 OUTPUT VOLTAGE TEMPERATURE DRIFT



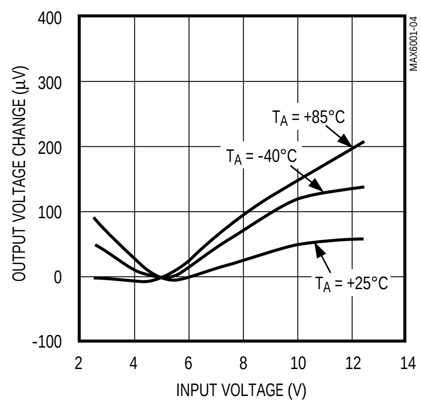
MAX6005 OUTPUT VOLTAGE TEMPERATURE DRIFT



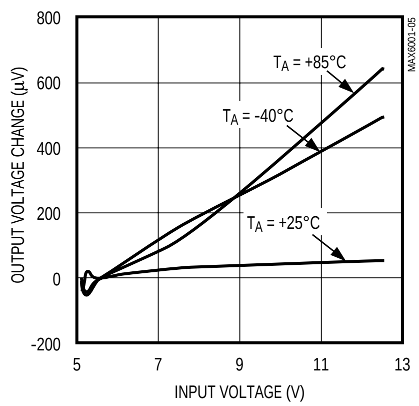
MAX6005 LONG-TERM DRIFT



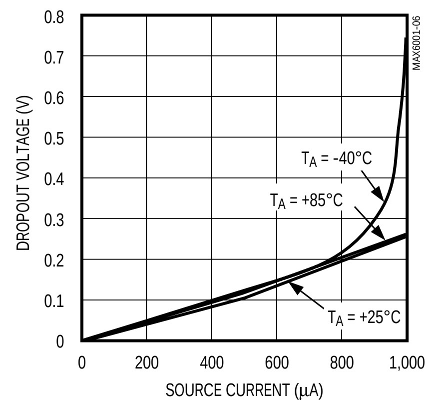
MAX6001 LINE REGULATION



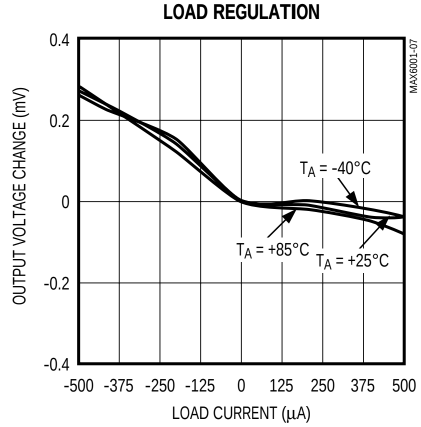
MAX6005 LINE REGULATION



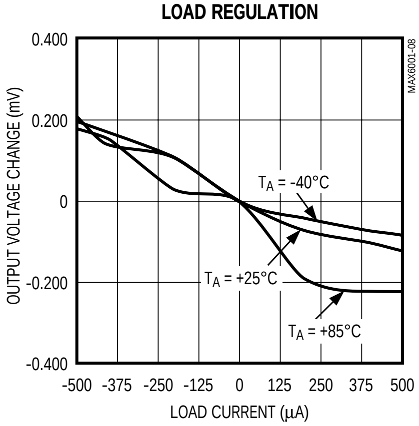
MAX6002/MAX6003 DROPOUT VOLTAGE vs. SOURCE CURRENT



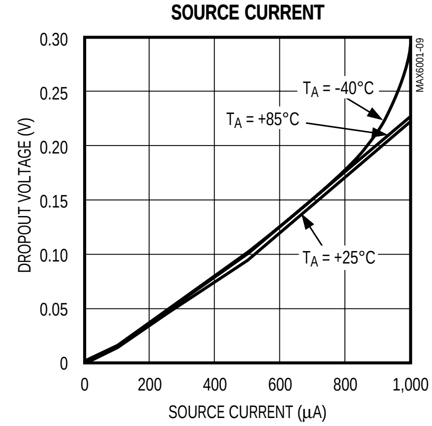
MAX6001 LOAD REGULATION



MAX6005 LOAD REGULATION



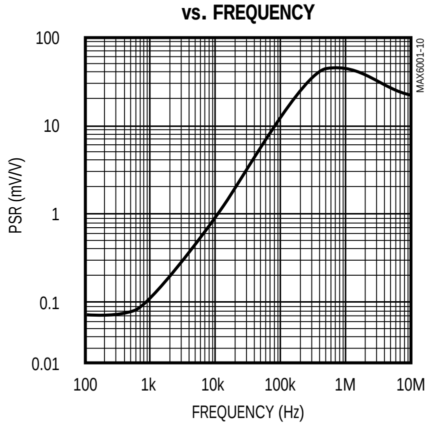
MAX6004/MAX6005 DROPOUT VOLTAGE vs. SOURCE CURRENT



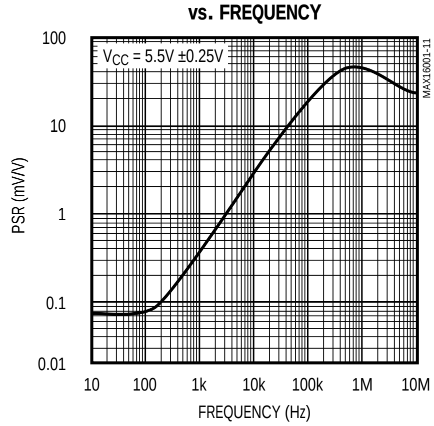
Typical Operating Characteristics (continued)

(V_{IN} = +5V for MAX6001–MAX6004, V_{IN} = +5.5V for MAX6005; I_{OUT} = 0; T_A = +25°C; unless otherwise noted.) (Note 6)

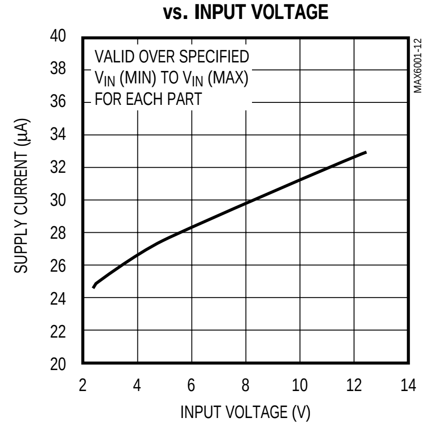
MAX6001 POWER-SUPPLY REJECTION vs. FREQUENCY



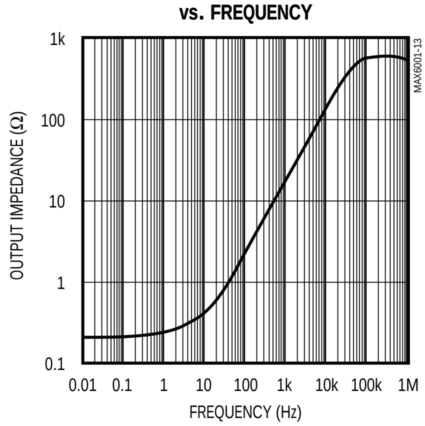
MAX6005 POWER-SUPPLY REJECTION vs. FREQUENCY



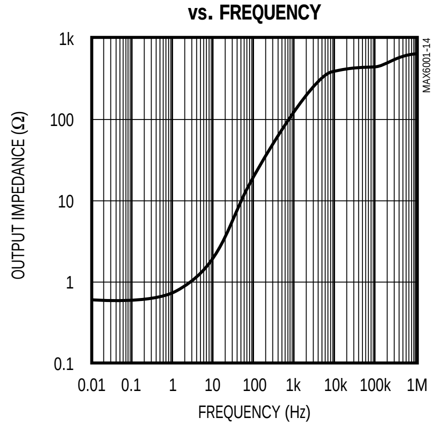
SUPPLY CURRENT vs. INPUT VOLTAGE



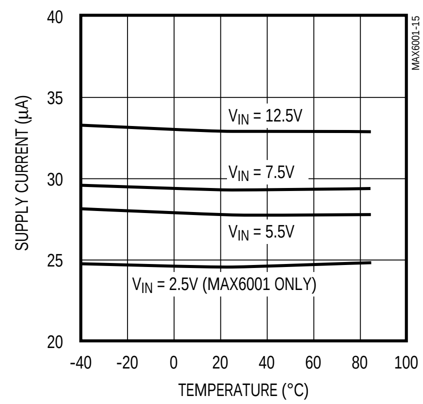
MAX6001 OUTPUT IMPEDANCE vs. FREQUENCY



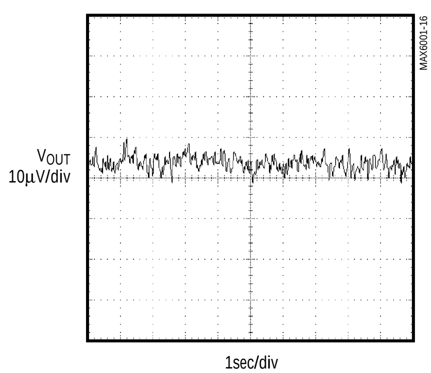
MAX6005 OUTPUT IMPEDANCE vs. FREQUENCY



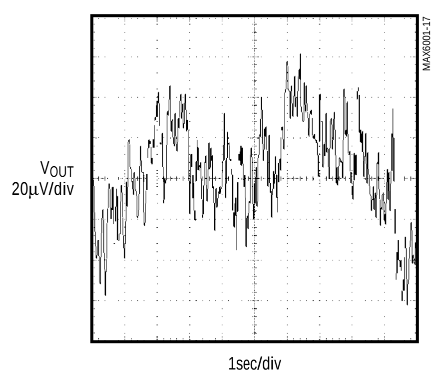
SUPPLY CURRENT vs. TEMPERATURE



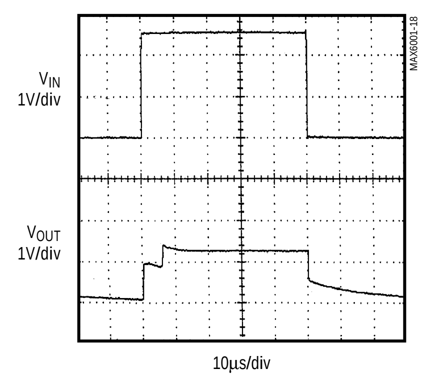
MAX6001 0.1Hz TO 10Hz OUTPUT NOISE



MAX6005 0.1Hz TO 10Hz OUTPUT NOISE



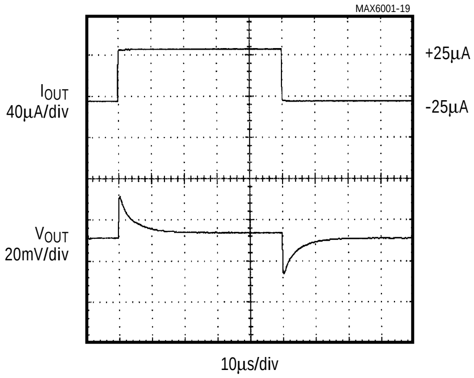
MAX6001 TURN-ON TRANSIENT



Typical Operating Characteristics (continued)

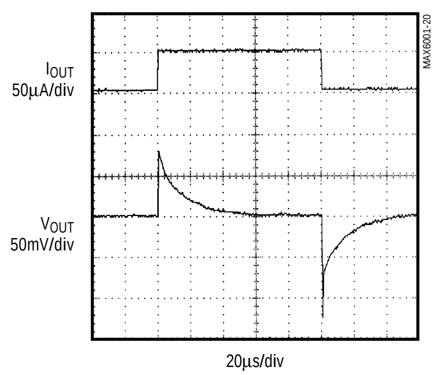
(V_{IN} = +5V for MAX6001–MAX6004, V_{IN} = +5.5V for MAX6005; I_{OUT} = 0; T_A = +25°C; unless otherwise noted.) (Note 6)

MAX6001
LOAD-TRANSIENT RESPONSE



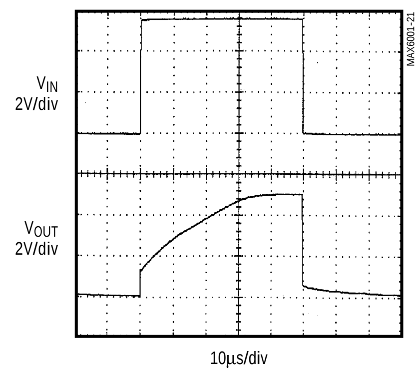
I_{OUT} = ±25µA, AC-COUPLED

MAX6005
LOAD-TRANSIENT RESPONSE

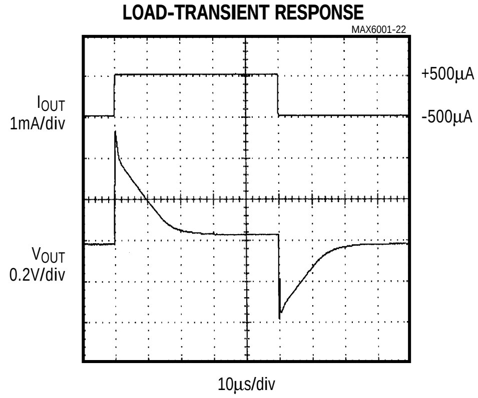


V_{IN} = 5.5V, I_{OUT} = ±25µA, AC-COUPLED

MAX6005
TURN-ON TRANSIENT

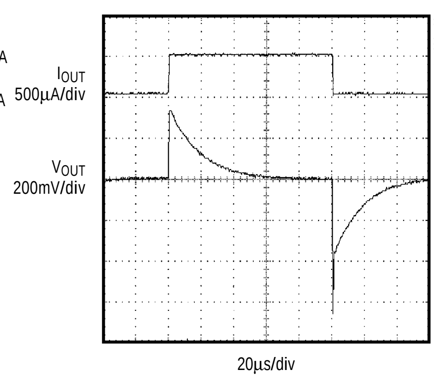


MAX6001
LOAD-TRANSIENT RESPONSE



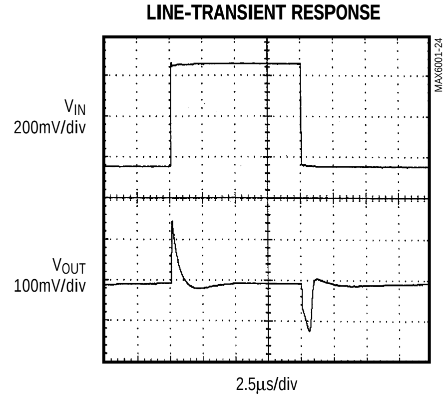
I_{OUT} = ±500µA, AC-COUPLED

MAX6005
LOAD-TRANSIENT RESPONSE



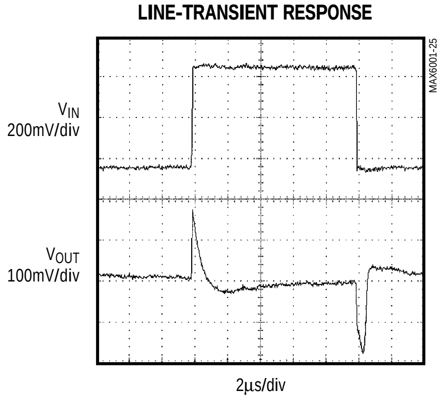
V_{IN} = 5.5V, I_{OUT} = ±500µA, AC-COUPLED

MAX6001
LINE-TRANSIENT RESPONSE



V_{IN} = 5V ±0.25V, AC-COUPLED

MAX6005
LINE-TRANSIENT RESPONSE



V_{IN} = 5.5V ±0.25V, AC-COUPLED

Note 6: Many of the *Typical Operating Characteristics* of the MAX6001 family are extremely similar. The extremes of these characteristics are found in the MAX6001 (1.2V output) and MAX6005 (5.0V output) devices. The *Typical Operating Characteristics* of the remainder of the MAX6001 family typically lie between these two extremes and can be estimated based on their output voltage.

Low-Cost, Low-Power, Low-Dropout, SOT23-3 Voltage References

Pin Description

PIN	NAME	FUNCTION
1	IN	Supply Voltage Input
2	OUT	Reference Voltage Output
3	GND	Ground

Detailed Description

The MAX6001–MAX6005 bandgap references offer a temperature coefficient of <100ppm/°C and initial accuracy of better than 1%. These devices can sink and source up to 400µA with <200mV of dropout voltage, making them attractive for use in low-voltage applications.

Applications Information

Output/Load Capacitance

Devices in this family do not require an output capacitance for frequency stability. They are stable for capacitive loads from 0 to 2.2nF. However, in applications where the load or the supply can experience step changes, an output capacitor will reduce the amount of overshoot (or undershoot) and assist the circuit's transient response. Many applications do not need an external capacitor, and this family can offer a significant advantage in these applications when board space is critical.

Supply Current

The quiescent supply current of these series-mode references is a maximum of 45µA and is virtually independent of the supply voltage, with only a 0.8µA/V variation with supply voltage. Unlike shunt-mode references, the load current of these series-mode references is drawn from the supply voltage only when required, so supply current is not wasted and efficiency is maximized over the entire supply voltage range. This improved efficiency can help reduce power dissipation and extend battery life.

When the supply voltage is below the minimum specified input voltage (as during turn-on), the devices can draw up to 200µA beyond the nominal supply current. The input voltage source must be capable of providing this current to ensure reliable turn-on.

Output Voltage Hysteresis

Output voltage hysteresis is the change in the output voltage at T_A = +25°C before and after the device is cycled over its entire operating temperature range. Hysteresis is caused by differential package stress appearing across the bandgap core transistors. The typical temperature hysteresis value is 130ppm.

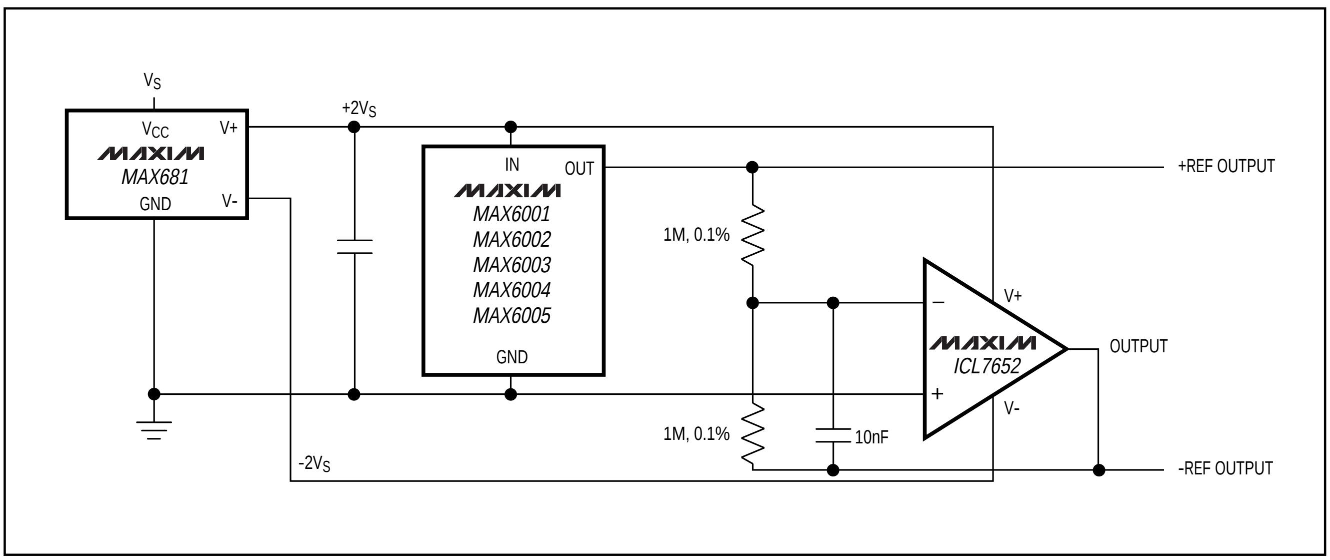


Figure 1. Positive and Negative References from Single +3V or +5V Supply

Turn-On Time

These devices typically turn on and settle to within 0.1% of their final value in 30µs to 220µs depending on the device. The turn-on time can increase up to 1.5ms with the device operating at the minimum dropout voltage and the maximum load.

Positive and Negative Low-Power Voltage Reference

Figure 1 shows a typical method for developing a bipolar reference. The circuit uses a MAX681 voltage doubler/inverter charge-pump converter to power an ICL7652, thus creating a positive as well as a negative reference voltage.

Chip Information

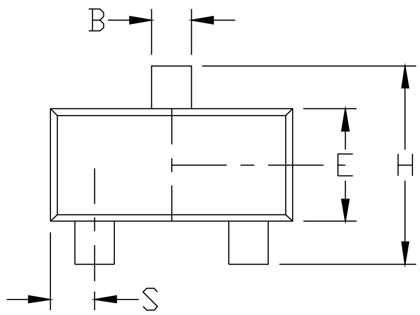
TRANSISTOR COUNT: 70

Low-Cost, Low-Power, Low-Dropout, SOT23-3 Voltage References

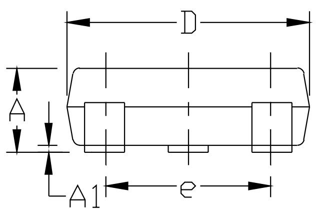
Package Information

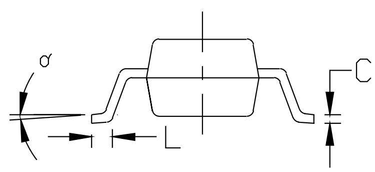
SOTPO3L.EPS

NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006")
3. CONTROLLING DIMENSION: MILLIMETER



	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.031	0.047	0.787	1.194
A1	0.001	0.005	0.025	0.127
B	0.014	0.022	0.356	0.559
C	0.0034	0.006	0.086	0.152
D	0.105	0.120	2.667	3.048
E	0.047	0.055	1.194	1.397
e	0.070	0.080	1.778	2.032
H	0.082	0.098	2.083	2.489
L	0.004	0.012	0.102	0.305
S	0.017	0.022	0.432	0.559
α	0°	8°	0°	8°





MAXIM
PROPRIETARY INFORMATION
TITLE: PACKAGE OUTLINE,SOT-23, 3L
APPROVAL | DOCUMENT CONTROL NO. 21-0051 | REV C | 1/1