19-1599; Rev 1; 4/00

MAXIM

Single/Dual/Quad, Low-Cost, Single-Supply, Rail-to-Rail Op Amps with Shutdown

General Description

The MAX4400–MAX4403 low-cost, general-purpose op amps offer Rail-to-Rail® outputs, draw only 320µA of quiescent current, and operate from a single +2.5V to +5.5V supply. For additional power conservation, the MAX4401 offers a low-power shutdown mode that reduces supply current to 1µA (max) and puts the amplifier's output in a high-impedance state. These devices deliver ±1.4mA of output current and are unity-gain stable with a 1MHz gain-bandwidth product driving capacitive loads up to 400pF. The MAX4400–MAX4403 are specified to +125°C, making them suitable for use in a variety of harsh environments, such as automotive applications.

The MAX4400 single amplifier is available in ultra-small 5-pin SC70 and space-saving 5-pin SOT23 packages. The single MAX4401 includes the shutdown feature and is available in a 6-pin SC70. The MAX4402 is a dual amplifier available in 8-pin SOT23 and SO packages. The MAX4403 quad amplifier is packaged in a 14-pin TSSOP or SO.

Features

- **Single +2.5V to +5.5V Supply Voltage Range**
- **320µA Quiescent Current per Amplifier**
- **1µA max Shutdown Mode (MAX4401)**
- **Available in Space-Saving Packages**
  - **5-Pin SC70 (MAX4400)**
  - **6-Pin SC70 (MAX4401)**
  - **8-Pin SOT23 (MAX4402)**
- **110dB A_{VOL} with 2kΩ Load**
- **0.015% THD with 2kΩ Load**
- **Rail-to-Rail Output Voltage Swing**
- **1.4mA of Sink and Source Load Current**
- **Unity-Gain Stable up to C_{LOAD} = 400pF**
- **Ground-Sensing Inputs**

Selector Guide

PART	NO. OF AMPLIFIERS PER PACKAGE	SHUTDOWN MODE
MAX4400	1	No
MAX4401	1	Yes
MAX4402	2	No
MAX4403	4	No

Ordering Information

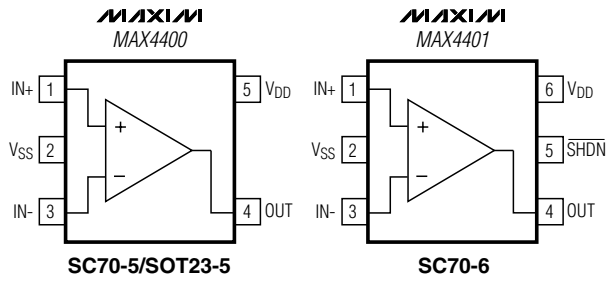
PART	TEMP. RANGE	PIN-PACKAGE	TOP MARK
MAX4400AXK-T	-40°C to +125°C	5 SC70-5	AAG
MAX4400AUK-T	-40°C to +125°C	5 SOT23-5	ADNP
MAX4401AXT-T	-40°C to +125°C	6 SC70-6	AAB
MAX4402AKA-T	-40°C to +125°C	8 SOT23-8	AADI
MAX4402ASA	-40°C to +125°C	8 SO	—
MAX4403AUD*	-40°C to +125°C	14 TSSOP	—
MAX4403ASD*	-40°C to +125°C	14 SO	—

**Future product—contact factory for availability.*

Applications

Single-Supply Zero-Crossing Detectors
Instruments and Terminals
Portable Communications
Electronic Ignition Modules
Infrared Receivers
Sensor Signal Detection

Pin Configurations



SC70-5/SOT23-5 SC70-6

Pin Configurations continued at end of data sheet.

Rail-to-Rail is a registered trademark of Nippon Motorola, Ltd.

Single/Dual/Quad, Low-Cost, Single-Supply, Rail-to-Rail Op Amps with Shutdown

ABSOLUTE MAXIMUM RATINGS

Power-Supply Voltage (V_{DD} to V_{SS}) .....-0.3V to +6V
All Other Pins .....(V_{SS} - 0.3V) to (V_{DD} + 0.3V)
Output Short-Circuit Duration
($\overline{OUT}$ shorted to V_{SS} or V_{DD})..... Continuous
Continuous Power Dissipation (T_A = +70°C)
5-Pin SC70 (derate 2.5mW/°C above +70°C)..... 200mW
6-Pin SC70 (derate 2.27mW/°C above +70°C).....181mW
5-Pin SOT23 (derate 7.1mW/°C above +70°C).....571mW
8-Pin SOT23 (derate 7.52mW/°C above +70°C).....602mW
8-Pin SO (derate 5.88mW/°C above +70°C)..... 471mW
14-Pin TSSOP (derate 8.33mW/°C above +70°C) 667mW
14-Pin SO (derate 8.33mW/°C above +70°C)..... 667mW
Operating Temperature Range .....-40°C to +125°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10s) .....+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

(V_{DD} = +5V, V_{SS} = 0, V_{CM} = 0, V_{OUT} = V_{DD}/2, R_L = ∞ connected to V_{DD}/2, $\overline{SHDN}$ = V_{DD} (MAX4401 only), **T_A = +25°C**, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage Range	V_{DD}	Inferred from PSRR test		2.5		5.5	V
Supply Current per Amplifier	I_{DD}	V_{DD} = 2.5V			320		µA
		V_{DD} = 5.0V			410	700	
Supply Current in Shutdown	I_{SHDN}	$\overline{SHDN}$ = V_{SS} (Note 1)			0.00002	1	µA
Input Offset Voltage	V_{OS}	MAX4400/MAX4401			±0.8	±4.5	mV
		MAX4402/MAX4403			±1.0	±5.5	
Input Bias Current	I_B	(Note 2)			±0.1	±100	pA
Input Offset Current	I_{OS}	(Note 2)			±0.1	±100	pA
Input Resistance	R_{IN}	Differential or common mode			1000		GΩ
Input Common-Mode Voltage Range	V_{CM}	Inferred from CMRR test		V_{SS}		V_{DD} - 1.4	V
Common-Mode Rejection Ratio	CMRR	V_{SS} ≤ V_{CM} ≤ V_{DD} - 1.4V		68	84		dB
Power-Supply Rejection Ratio	PSRR	2.5V ≤ V_{DD} ≤ 5.5V		78	100		dB
Large-Signal Voltage Gain	A_{VOL}	V_{SS} + 0.3V ≤ V_{OUT} ≤ V_{DD} - 0.3V	R_L = 100kΩ		120		dB
			R_L = 2kΩ	90	110		
Output Voltage High	V_{OH}	Specified as $\lvert V_{DD} - V_{OH} \rvert$	R_L = 100kΩ		3		mV
			R_L = 2kΩ		55	200	
Output Voltage Low	V_{OL}	Specified as $\lvert V_{SS} - V_{OL} \rvert$	R_L = 100kΩ		2		mV
			R_L = 2kΩ		30	75	
Output Short-Circuit Current		Sourcing			12		mA
		Sinking			30		
Shutdown Mode Output Leakage	$I_{OUTSHDN}$	Device in shutdown mode, $\overline{SHDN}$ = V_{SS}, V_{SS} < V_{OUT} < V_{CC} (Note 1)				±1.0	µA
$\overline{SHDN}$ Logic Low	V_{IL}	(Note 1)				0.3 × V_{DD}	V
$\overline{SHDN}$ Logic High	V_{IH}	(Note 1)		0.7 × V_{DD}			V
$\overline{SHDN}$ Input Current	I_{IL}, I_{IH}	$\overline{SHDN}$ = V_{DD} or V_{SS} (Notes 1, 2)			±1	±100	pA
Gain-Bandwidth Product	GBW				800		kHz
Phase Margin	ϕ_M				70		degrees
Gain Margin					20		dB
Slew Rate	SR				1		V/µs

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} = +5V, V_{SS} = 0, V_{CM} = 0, V_{OUT} = V_{DD}/2, R_L = ∞ connected to V_{DD}/2, $\overline{SHDN}$ = V_{DD} (MAX4401 only), **T_A = +25°C**, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Noise Density	e_n	f = 10kHz			36		nV/√Hz
Input Current Noise Density	i_n	f = 10kHz			1		fA/√Hz
Capacitive-Load Stability	C_{LOAD}	A_V = +1V/V			400		pF
Shutdown Delay Time	t_{SHDN}	(Note 1)			0.4		µs
Enable Delay Time	t_{EN}	(Note 1)			6		µs
Power-On Time	t_{ON}				5		µs
Input Capacitance	C_{IN}				2.5		pF
Total Harmonic Distortion	THD	f = 10kHz, V_{OUT} = 2Vp-p, A_V = +1V/V	R_L = 100kΩ		0.009		%
			R_L = 2kΩ		0.015		
Settling Time to 0.1%	t_S	V_{OUT} = 2V step			7		µs

ELECTRICAL CHARACTERISTICS

(V_{DD} = +5V, V_{SS} = 0, V_{CM} = 0, V_{OUT} = V_{DD}/2, R_L = ∞ connected to V_{DD}/2, **T_A = -40°C to +125°C**, unless otherwise noted.) (Note 3)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage Range	V_{DD}	Inferred from PSRR test		2.5		5.5	V
Supply Current per Amplifier	I_{DD}					800	µA
Input Offset Voltage	V_{OS}	MAX4400/MAX4401				±6.5	mV
		MAX4402/MAX4403				±8.0	
Input Offset Voltage Drift	TC_{VOS}				±1		µV/°C
Input Bias Current	I_B	(Note 2)				±100	pA
Input Offset Current	I_{OS}	(Note 2)				±100	pA
Input Common-Mode Voltage Range	V_{CM}	Inferred from CMRR test		V_{SS}		V_{DD} - 1.5	V
Common-Mode Rejection Ratio	CMRR	V_{SS} ≤ V_{CM} ≤ V_{DD} - 1.5V		65			dB
Power-Supply Rejection Ratio	PSRR	2.5V ≤ V_{CC} ≤ 5.5V		74			dB
Shutdown Mode Output Leakage	$I_{OUTSHDN}$	Device in shutdown mode, $\overline{SHDN}$ = V_{SS}, V_{SS} < V_{OUT} < V_{DD} (Note 1)	-40°C to +85°C			±1.0	µA
			+85°C to +125°C			±5.0	
$\overline{SHDN}$ Logic Low	V_{IL}	(Note 1)				0.3 × V_{DD}	V
$\overline{SHDN}$ Logic High	V_{IH}	(Note 1)		0.7 × V_{DD}			V
$\overline{SHDN}$ Input Current	I_{IL}, I_{IH}	$\overline{SHDN}$ = V_{DD} or V_{SS} (Notes 1, 2)				±100	pA
Large-Signal Voltage Gain	A_{VOL}	V_{SS} + 0.3V ≤ V_{OUT} ≤ V_{DD} - 0.3V, R_L = 2kΩ		85			dB
Output Voltage High	V_{OH}	Specified as |V_{DD} - V_{OH}|, R_L = 2kΩ				250	mV
Output Voltage Low	V_{OL}	Specified as |V_{SS} - V_{OL}|, R_L = 2kΩ				100	mV

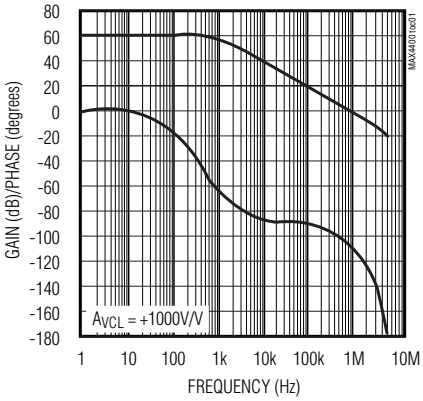
Note 1: Shutdown mode is only available in the 6-pin SC70 single op amp (MAX4401).
Note 2: Guaranteed by design.
Note 3: Specifications are 100% tested at T_A = +25°C (exceptions noted). All temperature limits are guaranteed by design.

Single/Dual/Quad, Low-Cost, Single-Supply, Rail-to-Rail Op Amps with Shutdown

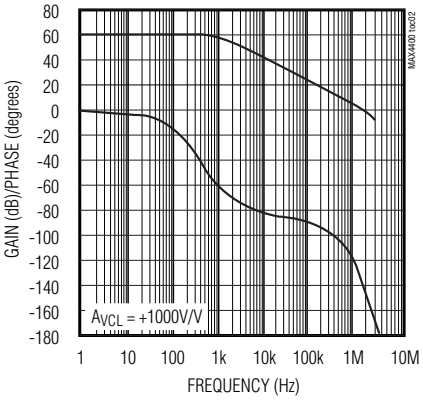
Typical Operating Characteristics

(V_{DD} = +5V, V_{SS} = 0, V_{CM} = V_{DD}/2, $V_{\overline{SHDN}}$ = 5V, R_L = ∞ connected to V_{DD}/2, T_A = +25°C, unless otherwise noted.)

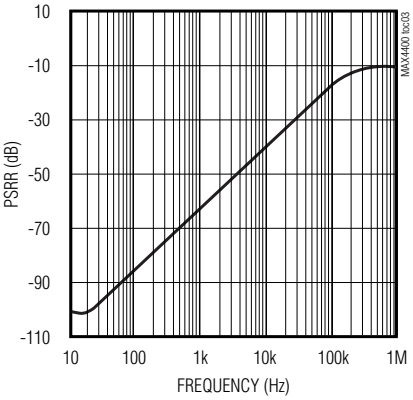
GAIN AND PHASE vs. FREQUENCY (NO LOAD)



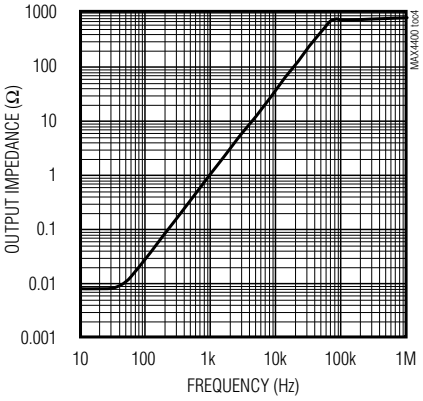
GAIN AND PHASE vs. FREQUENCY (C_L = 400pF)



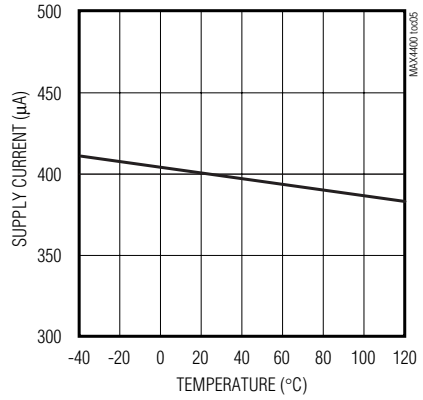
POWER-SUPPLY REJECTION RATIO vs. FREQUENCY



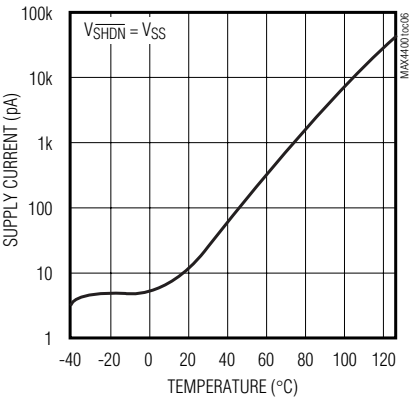
OUTPUT IMPEDANCE vs. FREQUENCY



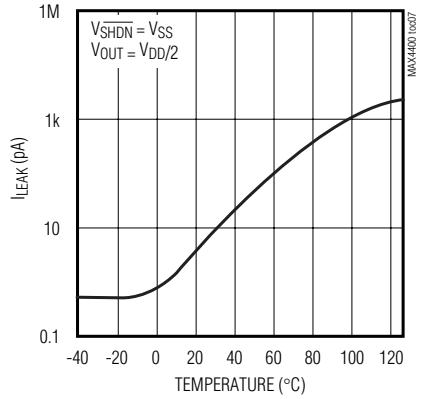
SUPPLY CURRENT vs. TEMPERATURE



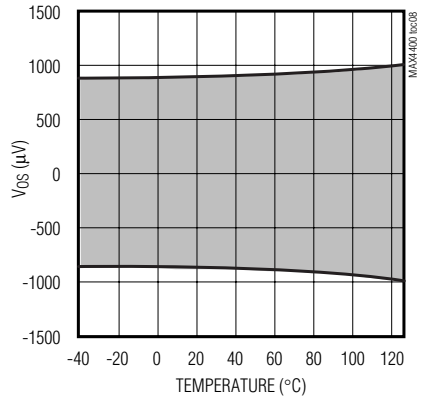
MAX4401 SHUTDOWN SUPPLY CURRENT vs. TEMPERATURE



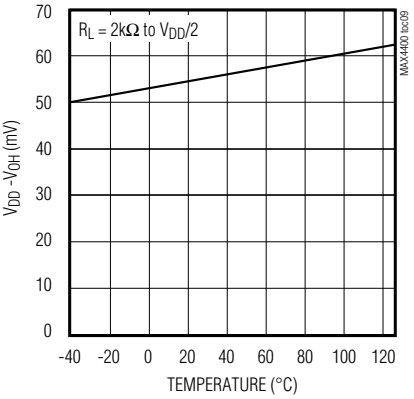
MAX4401 OUTPUT LEAKAGE CURRENT vs. TEMPERATURE



INPUT OFFSET VOLTAGE vs. TEMPERATURE



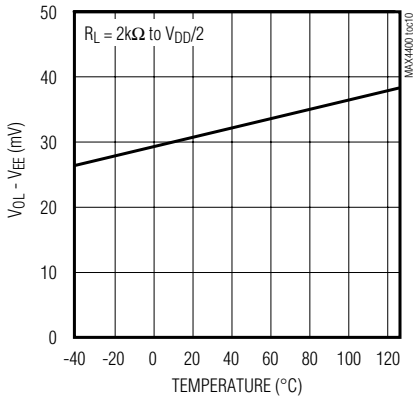
OUTPUT VOLTAGE SWING HIGH vs. TEMPERATURE



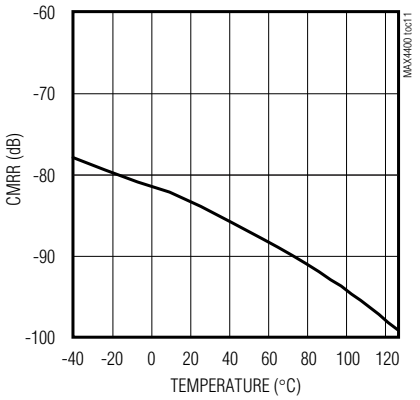
Typical Operating Characteristics (continued)

(V_{DD} = +5V, V_{SS} = 0, V_{CM} = V_{DD}/2, $V_{\overline{SHDN}}$ = 5V, R_L = ∞ connected to V_{DD}/2, T_A = +25°C, unless otherwise noted.)

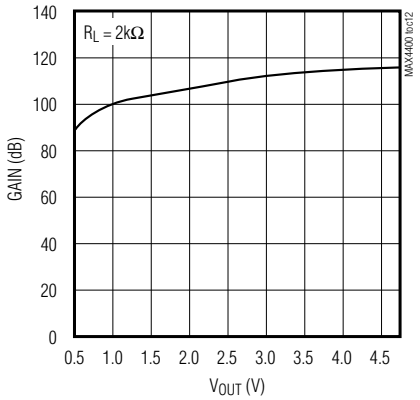
OUTPUT VOLTAGE SWING LOW vs. TEMPERATURE



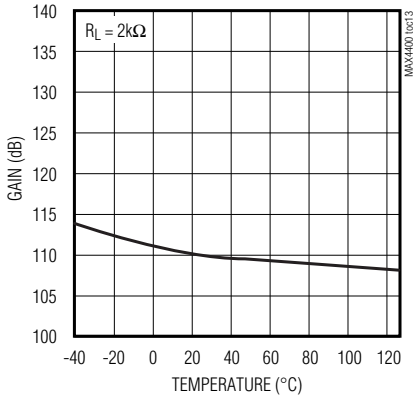
COMMON-MODE REJECTION RATIO vs. TEMPERATURE



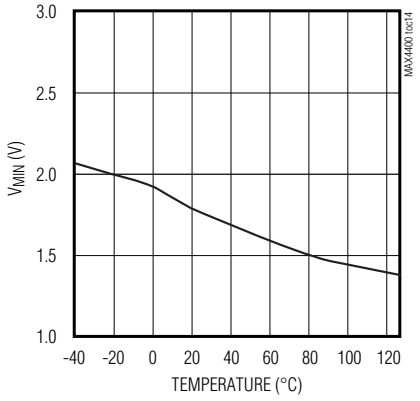
LARGE-SIGNAL GAIN vs. OUTPUT VOLTAGE



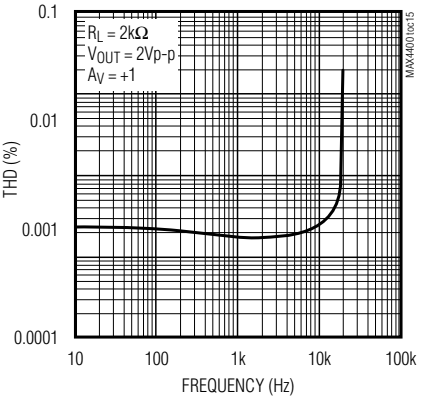
LARGE-SIGNAL GAIN vs. TEMPERATURE



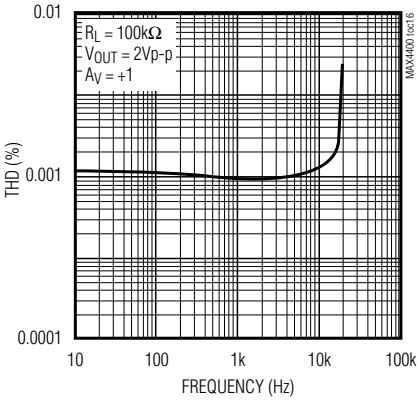
MINIMUM OPERATING VOLTAGE vs. TEMPERATURE



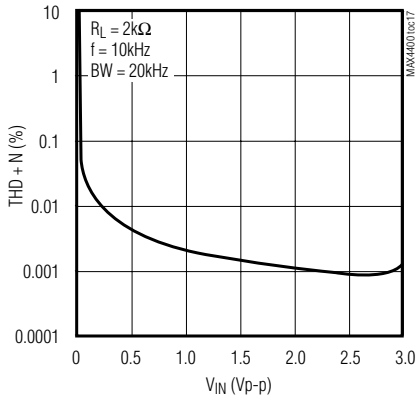
TOTAL HARMONIC DISTORTION vs. FREQUENCY



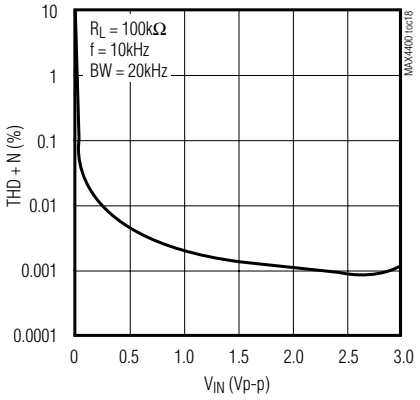
TOTAL HARMONIC DISTORTION vs. FREQUENCY



TOTAL HARMONIC DISTORTION PLUS NOISE vs. INPUT AMPLITUDE



TOTAL HARMONIC DISTORTION PLUS NOISE vs. INPUT AMPLITUDE

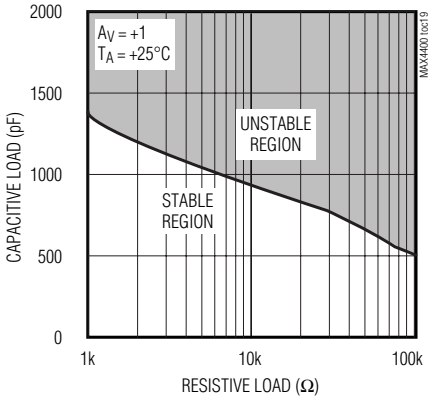


Single/Dual/Quad, Low-Cost, Single-Supply, Rail-to-Rail Op Amps with Shutdown

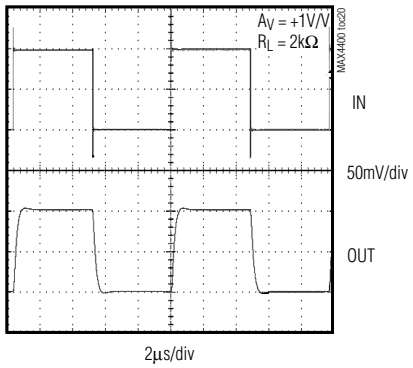
Typical Operating Characteristics (continued)

(V_{DD} = +5V, V_{SS} = 0, V_{CM} = V_{DD}/2, $V_{\overline{SHDN}}$ = 5V, R_L = ∞ connected to V_{DD}/2, T_A = +25°C, unless otherwise noted.)

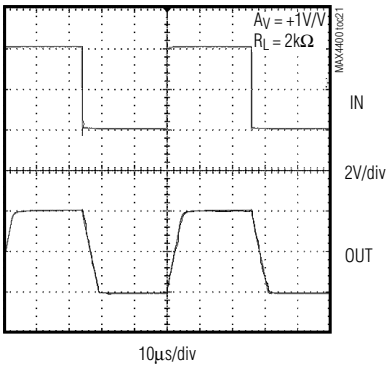
CAPACITIVE-LOAD STABILITY



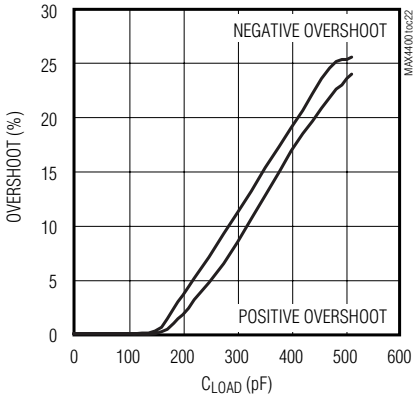
NONINVERTING SMALL-SIGNAL TRANSIENT RESPONSE



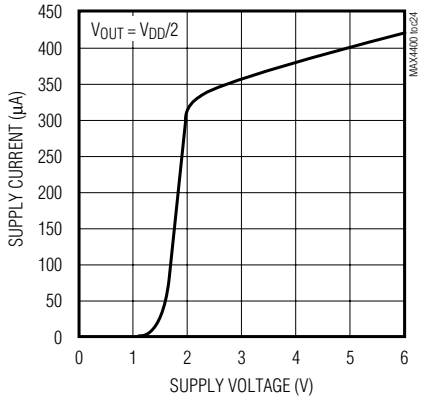
NONINVERTING LARGE-SIGNAL TRANSIENT RESPONSE



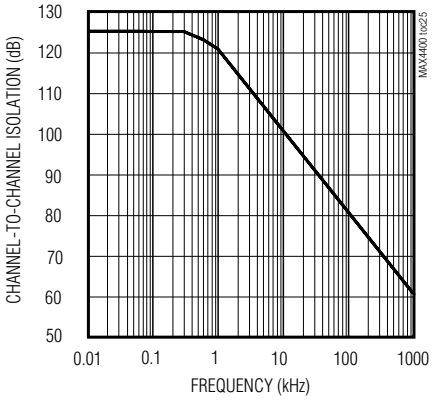
PERCENT OVERSHOOT vs. CAPACITIVE LOAD



SUPPLY CURRENT vs. SUPPLY VOLTAGE



MAX4402 CHANNEL-TO-CHANNEL ISOLATION vs. FREQUENCY



Pin Description

PIN				NAME	FUNCTION
MAX4400	MAX4401	MAX4402	MAX4403		
1	1	—	—	IN+	Noninverting Amplifier Input
—	—	3	3	INA+	Noninverting Amplifier Input A
—	—	5	5	INB+	Noninverting Amplifier Input B
—	—	—	10	INC+	Noninverting Amplifier Input C
—	—	—	12	IND+	Noninverting Amplifier Input D
2	2	4	11	V_{SS}	Negative Supply. Connect to ground for single-supply operation
3	3	—	—	IN-	Inverting Amplifier Input
—	—	2	2	INA-	Inverting Amplifier Input A
—	—	6	6	INB-	Inverting Amplifier Input B
—	—	—	9	INC-	Inverting Amplifier Input C
—	—	—	13	IND-	Inverting Amplifier Input D
4	4	—	—	OUT	Amplifier Output
—	—	1	1	OUTA	Amplifier Output A
—	—	7	7	OUTB	Amplifier Output B
—	—	—	8	OUTC	Amplifier Output C
—	—	—	14	OUTD	Amplifier Output D
5	6	8	4	V_{DD}	Positive Supply
—	5	—	—	$\overline{SHDN}$	Active-Low Shutdown Input. Connect to V_{DD} for normal operation. Do not leave floating.

Detailed Description

Rail-to-Rail Output Stage

The MAX4400–MAX4403 can drive a 2kΩ load and still typically swing within 55mV of the supply rails. Figure 1 shows the output voltage swing of the MAX4400 configured with A_V = +10V/V.

Driving Capacitive Loads

Driving a capacitive load can cause instability in many op amps, especially those with low quiescent current. The MAX4400–MAX4403 are unity-gain stable for a range of capacitive loads to above 400pF. Figure 2 shows the response of the MAX4400 with an excessive capacitive load. Adding a series resistor between the output and the load capacitor (Figure 3) improves the

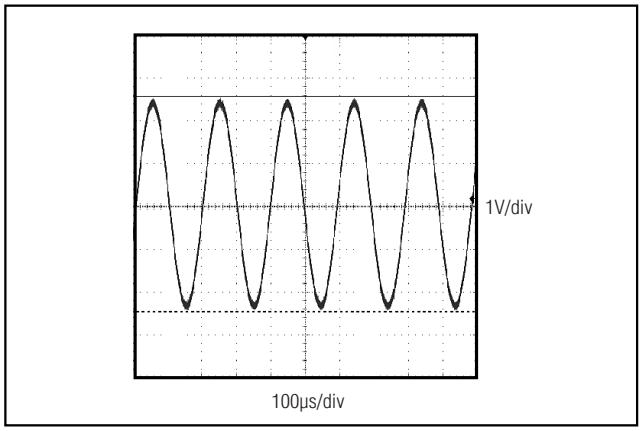


Figure 1. Rail-to-Rail Output Operation

Single/Dual/Quad, Low-Cost, Single-Supply, Rail-to-Rail Op Amps with Shutdown

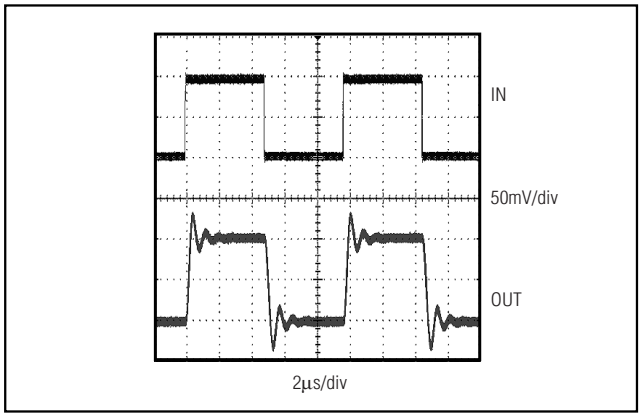


Figure 2. Small-Signal Transient Response with Excessive Capacitive Load

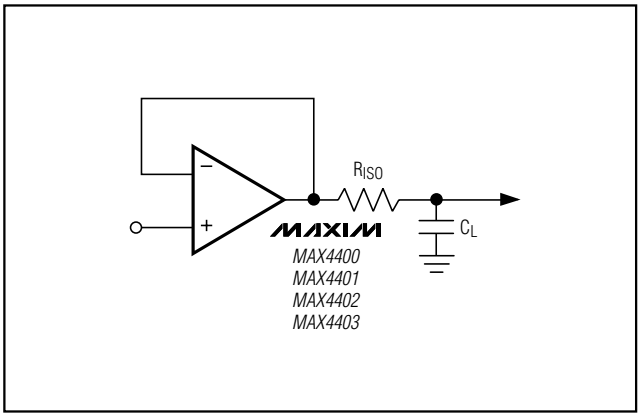


Figure 3. Capacitive-Load-Driving Circuit

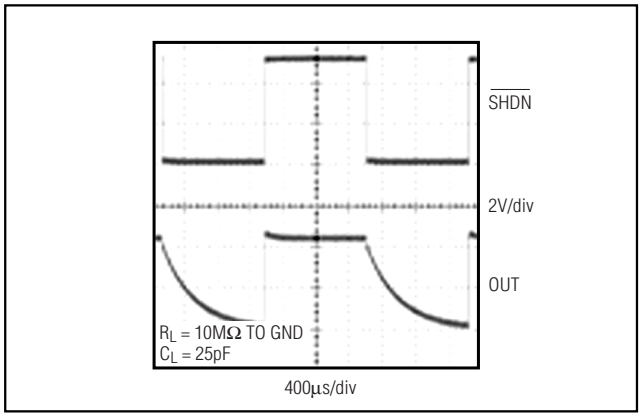


Figure 4. Shutdown Waveform

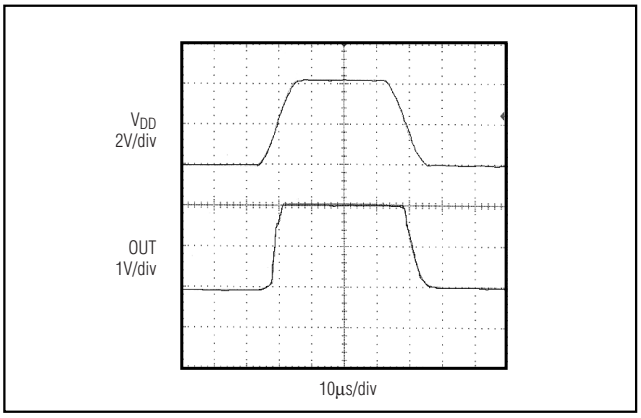


Figure 5. Power-Up/Power-Down Waveform

circuit's response by isolating the load capacitance from the op amp's output.

Applications Information

Shutdown Mode

The MAX4401 features a low-power shutdown mode. When $\overline{SHDN}$ goes low, the supply current drops to 20pA (typ) and the output enters a high-impedance state. Pull $\overline{SHDN}$ high to enable the amplifier. Do not leave $\overline{SHDN}$ floating. Figure 4 shows the shutdown waveform.

Power-Up

The MAX4400–MAX4403 outputs typically settle within 5µs after power-up. Figure 5 shows the output voltage on power-up and power-down.

Power Supplies and Layout

The MAX4400–MAX4403 operate from a single +2.5V to +5.5V power supply. Bypass the power supply with a 0.1µF capacitor to ground.

Good layout techniques optimize performance by decreasing the amount of stray capacitance at the op amp's inputs and outputs. To decrease stray capacitance, minimize trace lengths by placing external components close to the op amp's pins.

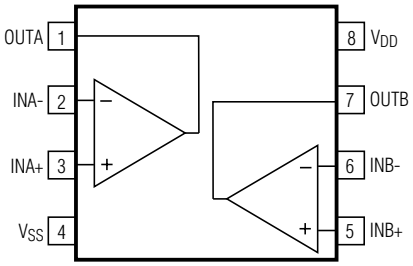
Chip Information

MAX4400/MAX4401 TRANSISTOR COUNT: 101
MAX4402 TRANSISTOR COUNT: 202
MAX4403 TRANSISTOR COUNT: 404

Single/Dual/Quad, Low-Cost, Single-Supply, Rail-to-Rail Op Amps with Shutdown

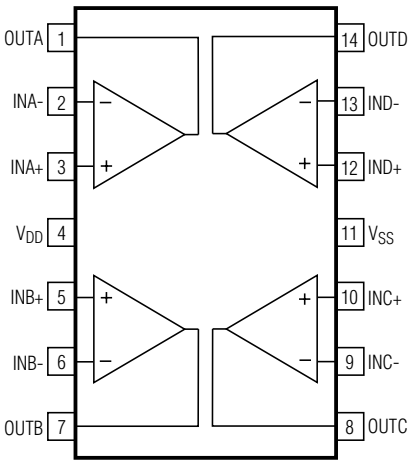
Pin Configurations (continued)

MAXIM
MAX4402



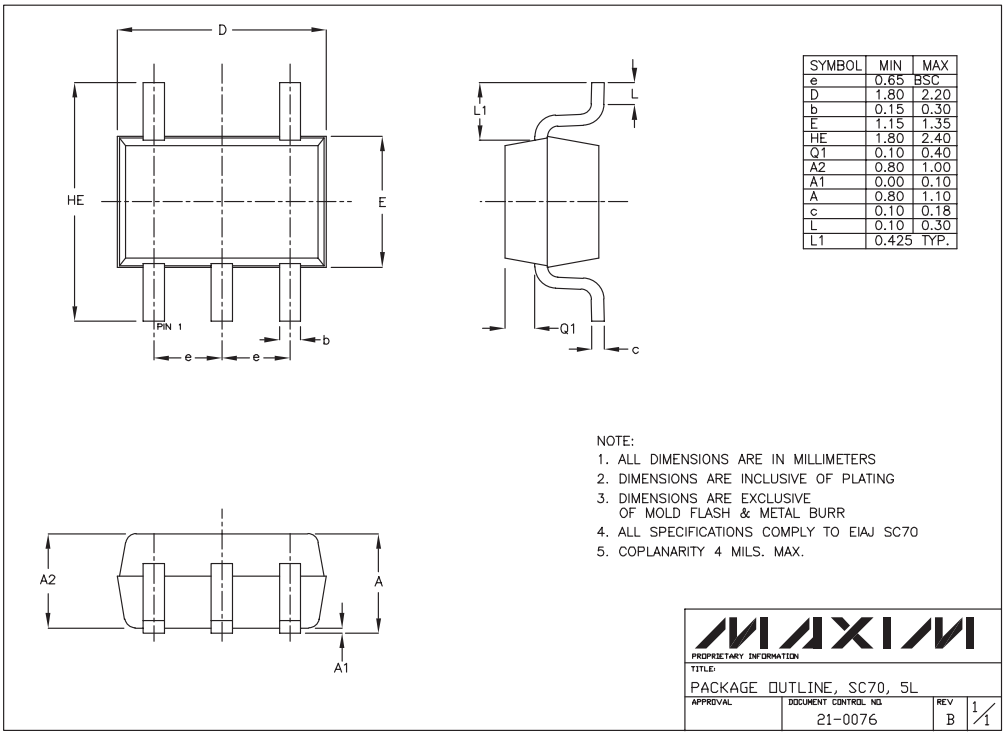
SOT23-8/SO

MAXIM
MAX4403



TSSOP/SO

Package Information

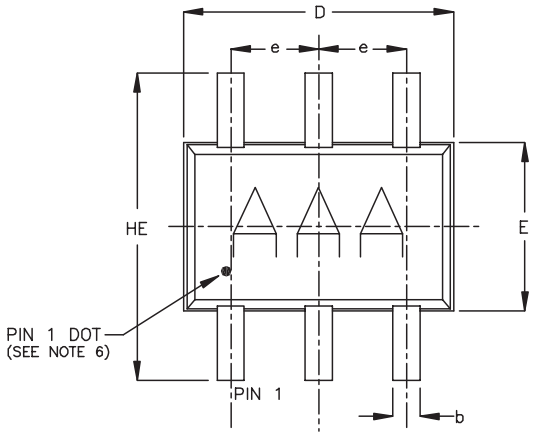


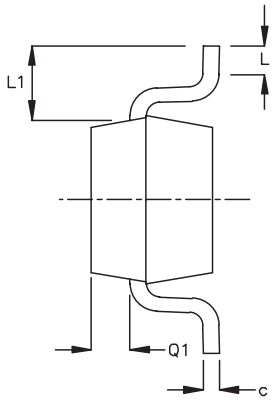
SYMBOL	MIN	MAX
e	0.65 BSC	
D	1.80	2.20
b	0.15	0.30
E	1.15	1.35
HE	1.80	2.40
Q1	0.10	0.40
A2	0.80	1.00
A1	0.00	0.10
A	0.80	1.10
c	0.10	0.18
L	0.10	0.30
L1	0.425 TYP.	

Single/Dual/Quad, Low-Cost, Single-Supply, Rail-to-Rail Op Amps with Shutdown

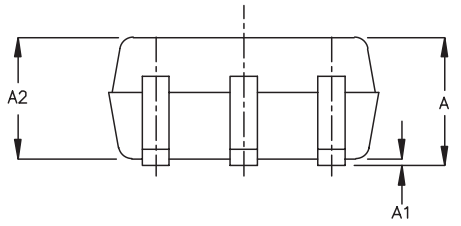
Package Information (continued)

SC70, 6L.EPS





SYMBOL	MIN	MAX
e	0.65 BSC	
D	1.80	2.20
b	0.15	0.30
E	1.15	1.35
HE	1.80	2.40
Q1	0.10	0.40
A2	0.80	1.00
A1	0.00	0.10
A	0.80	1.10
c	0.10	0.18
L	0.10	0.30
L1	0.425 TYP.	



1. ALL DIMENSIONS ARE IN MILLIMETERS
2. DIMENSIONS ARE INCLUSIVE OF PLATING
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR
4. ALL SPECIFICATIONS COMPLY TO EIAJ SC70
5. COPLANARITY 4 MILS. MAX.
6. PIN 1 I.D. DOT

MAXIM

PROPRIETARY INFORMATION

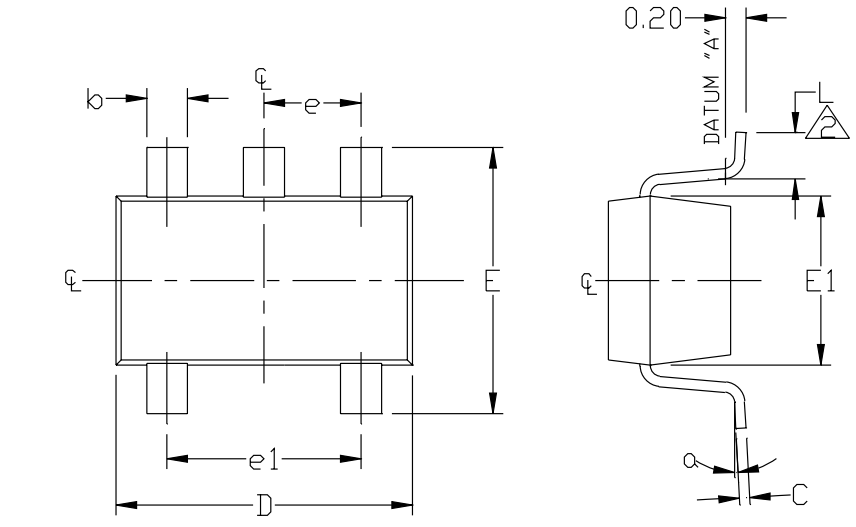
TITLE:

PACKAGE OUTLINE, SC70, 6L

APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0077	B	1/1

Package Information (continued)

SOT5L.EPS



SYMBOL	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
b	0.35	0.50
C	0.08	0.20
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.75
L	0.35	0.55
e	0.95 REF	
e1	1.90 REF	
a	0°	10°

NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM A & LEAD SURFACE.
3. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. PACKAGE OUTLINE INCLUSIVE OF SOLDER PLATING.

MAXIM

PROPRIETARY INFORMATION

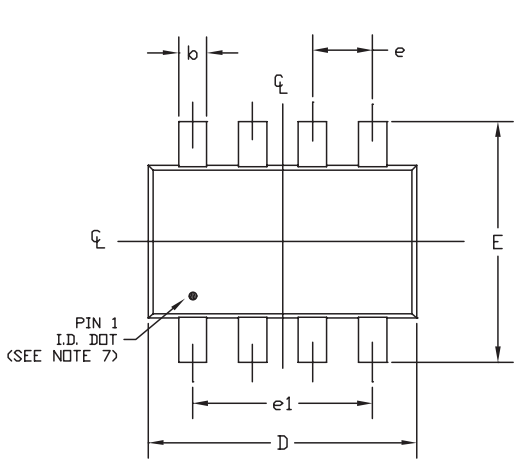
TITLE: PACKAGE OUTLINE, SOT23, 5L

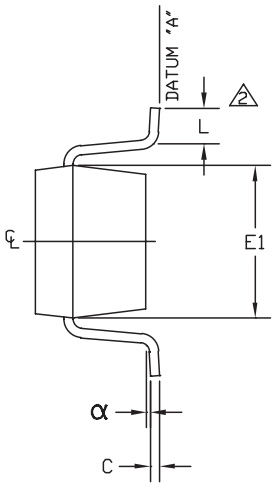
APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0057	B	1/1

Single/Dual/Quad, Low-Cost, Single-Supply, Rail-to-Rail Op Amps with Shutdown

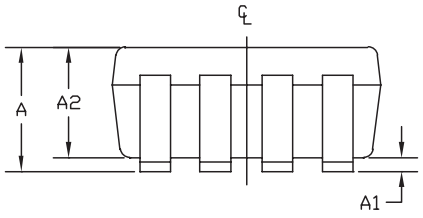
Package Information (continued)

SOT23, 8L.EPS





SYMBOL	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
b	0.28	0.45
C	0.09	0.20
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.75
L	0.10	0.60
e	0.65 ref	
e1	1.95 ref	
α	0°	10°



NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. FOOT LENGTH MEASURED REFERENCE TO FLAT FOOT SURFACE PARALLEL TO DATUM "A".
3. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. PACKAGE OUTLINE INCLUSIVE OF SOLDER PLATING.
5. EIAJ REF. NUMBER" SC-74 (6 LEAD VERSION)
6. COPLANARITY 4 MILS. MAX.
7. PIN 1 I.D. DOT IS 0.3 MM ø MIN. LOCATED ABOVE PIN 1.

MAXIM
PROPRIETARY INFORMATION

TITLE:
PACKAGE OUTLINE, SOT 23, 8L

APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0078	B	1/1