19-1343; Rev 0; 3/98

MAXIM

Single/Dual/Quad, +1.8V/10µA, SOT23, Beyond-the-Rails Op Amps

General Description

The MAX4240–MAX4244 family of micropower op amps operate from a single +1.8V to +5.5V supply or dual ±0.9V to ±2.75V supplies and have Beyond-the-Rails™ inputs and Rail-to-Rail® output capabilities. These amplifiers provide a 90kHz gain-bandwidth product while using only 10µA of supply current per amplifier. The MAX4241/MAX4243 have a low-power shutdown mode that reduces supply current to less than 1µA and forces the output into a high-impedance state. Although the minimum operating voltage is specified at +1.8V, these devices typically operate down to +1.5V. The combination of ultra-low-voltage operation, beyond-the-rails inputs, rail-to-rail outputs, and ultra-low power consumption makes these devices ideal for any portable/two-cell battery-powered system.

These amplifiers have an input common-mode range that extends 200mV beyond each rail, and their outputs typically swing to within 9mV of the rails with a 100kΩ load. Beyond-the-rails input and rail-to-rail output characteristics allow the full power-supply voltage to be used for signal range. The combination of low input offset voltage, low input bias current, and high open-loop gain makes them suitable for low-power/low-voltage precision applications.

The MAX4240 is offered in a space-saving 5-pin SOT23 package. All specifications are guaranteed over the -40°C to +85°C extended temperature range.

Applications

- Two-Cell Battery-Powered Systems
- Portable/Battery-Powered Electronic Equipment
- Digital Scales
- Strain Gauges
- Sensor Amplifiers
- Cellular Phones
- Notebook Computers
- PDAs

Selector Guide

PART	NO. OF AMPS	SHUTDOWN	PIN-PACKAGE
MAX4240	1	—	5-pin SOT23
MAX4241	1	Yes	8-pin µMAX/SO
MAX4242	2	—	8-pin µMAX/SO
MAX4243	2	Yes	10-pin µMAX, 14-pin SO
MAX4244	4	—	14-pin SO

Beyond-the-Rails is a trademark of Maxim Integrated Products.
Rail-to-Rail is a registered trademark of Nippon Motorola Ltd.

Features

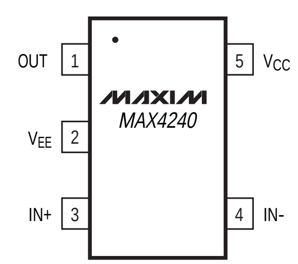
- **Ultra-Low-Voltage Operation:**
  Guaranteed Down to +1.8V
  Typical Operation to +1.5V
- **Ultra-Low Power Consumption:**
  10µA Supply Current per Amplifier
  1µA Shutdown Mode (MAX4241/MAX4243)
  Up to 200,000 Hours Operation from Two AA Alkaline Cells
- **Beyond-the-Rails Input Common-Mode Range**
- **Outputs Swing Rail-to-Rail**
- **No Phase Reversal for Overdriven Inputs**
- **200µV Input Offset Voltage**
- **Unity-Gain Stable for Capacitive Loads up to 200pF**
- **90kHz Gain-Bandwidth Product**
- **Available in Space-Saving 5-Pin SOT23 and 8-Pin µMAX Packages**

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	SOT TOP MARK
MAX4240EUK-T	-40°C to +85°C	5 SOT23-5	ACCS
MAX4241EUA	-40°C to +85°C	8 µMAX	—
MAX4241ESA	-40°C to +85°C	8 SO	—
MAX4242EUA	-40°C to +85°C	8 µMAX	—
MAX4242ESA	-40°C to +85°C	8 SO	—
MAX4243EUB	-40°C to +85°C	10 µMAX	—
MAX4243ESD	-40°C to +85°C	14 SO	—
MAX4244ESD	-40°C to +85°C	14 SO	—

Pin Configurations

TOP VIEW



SOT23-5

Pin Configurations continued at end of data sheet.

Single/Dual/Quad, +1.8V/10µA, SOT23, Beyond-the-Rails Op Amps

ABSOLUTE MAXIMUM RATINGS

Supply Voltage (V_{CC} to V_{EE})..6V
All Other Pins ....(V_{CC} + 0.3V) to (V_{EE} - 0.3V)
Output Short-Circuit Duration (to V_{CC} or V_{EE})............Continuous
Continuous Power Dissipation (T_A = +70°C)
5-pin SOT23 (derate 7.1mW/°C above +70°C).............571mW
8-pin µMAX (derate 4.1mW/°C above +70°C) 330mW
8-pin SO (derate 5.88mW/°C above +70°C).................471mW
10-pin µMAX (derate 5.6mW/°C above +70°C) 444mW
14-pin SO (derate 8.33mW/°C above +70°C)...............667mW
Operating Temperature Range ....-40°C to +85°C
Junction Temperature..+150°C
Storage Temperature Range ....-65°C to +160°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 — T_A = +25°C

(V_{CC} = +1.8V to +5.5V, V_{EE} = 0, V_{CM} = 0, V_{OUT} = V_{CC} / 2, R_L = 100kΩ tied to V_{CC} / 2, $\overline{SHDN}$ = V_{CC}, T_A = +25°C, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply-Voltage Range	V_{CC}	Inferred from PSRR test		1.8		5.5	V
Supply Current per Amplifier	I_{CC}	$\overline{SHDN}$ = V_{CC}	V_{CC} = 1.8V		10	12	µA
			V_{CC} = 5.0V		14	18	
Shutdown Supply Current (Note 2)	$I_{CC(\overline{SHDN})}$	$\overline{SHDN}$ = V_{EE}	V_{CC} = 1.8V		1.0	1.5	µA
			V_{CC} = 5.0V		2.0	3.0	
Input Offset Voltage	V_{OS}	(V_{EE} - 0.2V) ≤ V_{CM} ≤ (V_{CC} + 0.2V)	MAX4241ESA		±0.20	±0.75	mV
			MAX4242ESA/MAX4243ESD/ MAX4244ESD		±0.20	±0.88	
			MAX4240EUK/MAX424_EUA/ MAX4243EUB		±0.25	±1.40	
Input Bias Current	I_B	(Note 3)			±2	±6	nA
Input Offset Current	I_{OS}	(Note 3)			±0.5	±1.5	nA
Differential Input Resistance	$R_{IN(DIFF)}$	$\lvert V_{IN+} - V_{IN-} \rvert$ < 1.0V			45		MΩ
		$\lvert V_{IN+} - V_{IN-} \rvert$ > 2.5V			4.4		kΩ
Input Common-Mode Voltage Range	V_{CM}	Inferred from the CMRR test		V_{EE} - 0.2		V_{CC} + 0.2	V
Common-Mode Rejection Ratio (Note 4)	CMRR	V_{CC} = 1.8V	MAX4241ESA	72	90		dB
			MAX4242ESA/MAX4243ESD/ MAX4244ESD	72	90		
			MAX4240EUK/MAX424_EUA/ MAX4243EUB	66	88		
		V_{CC} = 5.0V	MAX4241ESA	77	94		
			MAX4242ESA/MAX4243ESD/ MAX4244ESD	77	94		
			MAX4240EUK/MAX424_EUA/ MAX4243EUB	72	90		

ELECTRICAL CHARACTERISTICS — T_A = +25°C (continued)

(V_{CC} = +1.8V to +5.5V, V_{EE} = 0, V_{CM} = 0, V_{OUT} = V_{CC} / 2, R_L = 100kΩ tied to V_{CC} / 2, $\overline{SHDN}$ = V_{CC}, T_A = +25°C, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS			MIN	TYP	MAX	UNITS
Power-Supply Rejection Ratio	PSRR	1.8V ≤ V_{CC} ≤ 5.5V	MAX4241ESA		80	85		dB
			MAX4242ESA/MAX4243ESD/ MAX4244ESD		80	85		
			MAX4240EUK/MAX424_EUA/ MAX4243EUB		78	82		
Large-Signal Voltage Gain	A_{VOL}	(V_{EE} + 0.2V) ≤ V_{OUT} ≤ (V_{CC} - 0.2V)	V_{CC} = 1.8V	R_L = 100kΩ	80	85		dB
				R_L = 10kΩ	70	73		
			V_{CC} = 5.0V	R_L = 100kΩ	90	94		
				R_L = 10kΩ	82	85		
Output Voltage Swing High	V_{OH}	Specified as $\|V_{CC} - V_{OH}\|$	V_{CC} = 1.8V	R_L = 100kΩ		8	20	mV
				R_L = 10kΩ		40	65	
			V_{CC} = 5.0V	R_L = 100kΩ		10	25	
				R_L = 10kΩ		60	95	
Output Voltage Swing Low	V_{OL}	Specified as $\|V_{EE} - V_{OL}\|$	V_{CC} = 1.8V	R_L = 100kΩ		6	15	mV
				R_L = 10kΩ		23	35	
			V_{CC} = 5.0V	R_L = 100kΩ		10	20	
				R_L = 10kΩ		40	60	
Output Short-Circuit Current	$I_{OUT(SC)}$	Sourcing				0.7		mA
		Sinking				2.5		
Output Leakage Current in Shutdown (Notes 2, 5)	$I_{OUT(\overline{SHDN})}$	$\overline{SHDN}$ = V_{EE} = 0, V_{CC} = 5.5V				20	50	nA
$\overline{SHDN}$ Logic Low (Note 2)	V_{IL}						0.3 x V_{CC}	V
$\overline{SHDN}$ Logic High (Note 2)	V_{IH}				0.7 x V_{CC}			V
$\overline{SHDN}$ Input Bias Current (Note 2)	I_{IH}, I_{IL}	$\overline{SHDN}$ = V_{CC} = 5.5V or $\overline{SHDN}$ = V_{EE} = 0				40	80	nA
Channel-to-Channel Isolation (Note 6)	CH_{ISO}	Specified at DC				80		dB
Gain-Bandwidth Product	GBW					90		kHz
Phase Margin	Φ_m					68		degrees
Gain Margin	G_m					18		dB
Slew Rate	SR					40		V/ms

ELECTRICAL CHARACTERISTICS — T_A = +25°C (continued)

(V_{CC} = +1.8V to +5.5V, V_{EE} = 0, V_{CM} = 0, V_{OUT} = V_{CC} / 2, R_L = 100kΩ tied to V_{CC} / 2, $\overline{SHDN}$ = V_{CC}, T_A = +25°C, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Noise Density	e_n	f = 1kHz		70		nV/√Hz
Input Current Noise Density	i_n	f = 1kHz		0.05		pA/√Hz
Capacitive-Load Stability		A_{VCL} = +1V/V, no sustained oscillations		200		pF
Shutdown Time	$t_{\overline{SHDN}}$			50		µs
Enable Time from Shutdown	t_{ENABLE}			150		µs
Power-Up Time	t_{ON}			200		µs
Input Capacitance	C_{IN}			3		pF
Total Harmonic Distortion	THD	f_{IN} = 1kHz, V_{CC} = 5.0V, V_{OUT} = 2Vp-p, A_V = +1V/V		0.05		%
Settling Time to 0.01%	t_S	A_V = +1V/V, V_{CC} = 5.0V, V_{OUT} = $2V_{STEP}$		50		µs

ELECTRICAL CHARACTERISTICS — T_A = T_{MIN} to T_{MAX}

(V_{CC} = +1.8V to +5.5V, V_{EE} = 0, V_{CM} = 0, V_{OUT} = V_{CC} / 2, R_L = 100kΩ tied to V_{CC} / 2, $\overline{SHDN}$ = V_{CC}, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply-Voltage Range	V_{CC}	Inferred from PSRR test		1.8		5.5	V
Supply Current per Amplifier	I_{CC}	$\overline{SHDN}$ = V_{CC}	V_{CC} = 1.8V			14	µA
			V_{CC} = 5.0V			19	
Shutdown Supply Current (Note 2)	$I_{CC(\overline{SHDN})}$	$\overline{SHDN}$ = V_{EE}	V_{CC} = 1.8V			2.0	µA
			V_{CC} = 5.0V			3.5	
Input Offset Voltage	V_{OS}	(V_{EE} - 0.2V) ≤ V_{CM} ≤ (V_{CC} + 0.2V)	MAX4241ESA			±1.2	mV
			MAX4242ESA/MAX4243ESD/ MAX4244ESD			±1.3	
			MAX4240EUK/MAX424_EUA/ MAX4243EUB			±2.0	
Input Offset Voltage Drift	TC_{VOS}				2		µV/°C
Input Bias Current	I_B	(Note 3)				±15	nA
Input Offset Current	I_{OS}	(Note 3)				±7	nA
Input Common-Mode Voltage Range	V_{CM}	Inferred from the CMRR test		-0.2		V_{CC} + 0.2	V

ELECTRICAL CHARACTERISTICS — $T_A = T_{MIN}$ to T_{MAX} (continued)

(V_{CC} = +1.8V to +5.5V, V_{EE} = 0, V_{CM} = 0, V_{OUT} = V_{CC} / 2, R_L = 100kΩ tied to V_{CC} / 2, $\overline{SHDN}$ = V_{CC}, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS			MIN	TYP	MAX	UNITS
Common-Mode Rejection Ratio (Note 4)	CMRR	V_{CC} = 1.8V	MAX4241ESA		68			dB
			MAX4242ESA/MAX4243ESD/ MAX4244ESD		68			
			MAX4240EUK/MAX424_EUA/ MAX4243EUB		64			
		V_{CC} = 5.0V	MAX4241ESA		74			
			MAX4242ESA/MAX4243ESD/ MAX4244ESD		74			
			MAX4240EUK/MAX424_EUA/ MAX4243EUB		70			
Power-Supply Rejection Ratio	PSRR	1.8V ≤ V_{CC} ≤ 5.5V	MAX4241ESA		76			dB
			MAX4242ESA/MAX4243ESD/ MAX4244ESD		76			
			MAX4240EUK/MAX424_EUA/ MAX4243EUB		74			
Large-Signal Voltage Gain	A_{VOL}	(V_{EE} + 0.2V) ≤ V_{OUT} ≤ (V_{CC} - 0.2V)	V_{CC} = 1.8V	R_L = 100kΩ	76			dB
				R_L = 10kΩ	66			
			V_{CC} = 5.0V	R_L = 100kΩ	84			
				R_L = 10kΩ	76			
Output Voltage Swing High	V_{OH}	Specified as $\lvert V_{CC} - V_{OH} \rvert$	V_{CC} = 1.8V	R_L = 100kΩ			25	dB
				R_L = 10kΩ			95	
			V_{CC} = 5.0V	R_L = 100kΩ			30	
				R_L = 10kΩ			145	
Output Voltage Swing Low	V_{OL}	Specified as $\lvert V_{EE} - V_{OL} \rvert$	V_{CC} = 1.8V	R_L = 100kΩ			20	dB
				R_L = 10kΩ			50	
			V_{CC} = 5.0V	R_L = 100kΩ			25	
				R_L = 10kΩ			75	
Output Leakage Current in Shutdown (Notes 2, 5)	$I_{OUT(\overline{SHDN})}$	$\overline{SHDN}$ = V_{EE} = 0, V_{CC} = 5.5V					100	nA
$\overline{SHDN}$ Logic Low (Note 2)	V_{IL}						0.3 x V_{CC}	V

ELECTRICAL CHARACTERISTICS — $T_A = T_{MIN}$ to T_{MAX} (continued)

(V_{CC} = +1.8V to +5.5V, V_{EE} = 0, V_{CM} = 0, $V_{OUT} = V_{CC}$ / 2, R_L = 100kΩ tied to V_{CC} / 2, $\overline{SHDN} = V_{CC}$, $T_A = T_{MIN}$ to T_{MAX}, unless otherwise noted.) (Note 1)

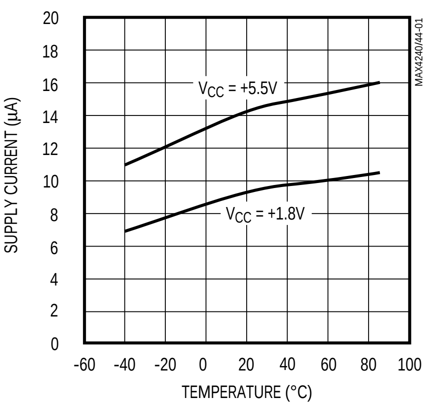
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
$\overline{SHDN}$ Logic High (Note 2)	V_{IH}		0.7 x V_{CC}			V
$\overline{SHDN}$ Input Bias Current (Note 2)	I_{IH}, I_{IL}	$\overline{SHDN} = V_{CC}$ = 5.5V or $\overline{SHDN} = V_{EE}$ = 0			120	nA

Note 1: The MAX4240EUK, MAX4241EUA, MAX4242EUA, and MAX4243EUB specifications are 100% tested at T_A = +25°C. All temperature limits are guaranteed by design.
Note 2: Shutdown mode applies to the MAX4241/MAX4243 only.
Note 3: Input bias current and input offset current are tested with V_{CC} = +5.0V and $0 \le V_{CM} \le 5.0V$.
Note 4: Tested over the specified input common-mode range.
Note 5: Tested for $0 \le V_{OUT} \le V_{CC}$. Does not include current through external feedback network.
Note 6: Channel-to-channel isolation specification applies to the MAX4242/MAX4243/MAX4244 only.

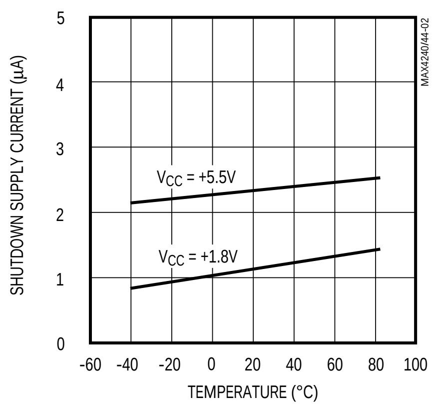
Typical Operating Characteristics

(V_{CC} = +5.0V, V_{EE} = 0, $V_{CM} = V_{CC}$ / 2, $V_{\overline{SHDN}} = V_{CC}$, R_L = 100kΩ to V_{CC} / 2, T_A = +25°C, unless otherwise noted.)

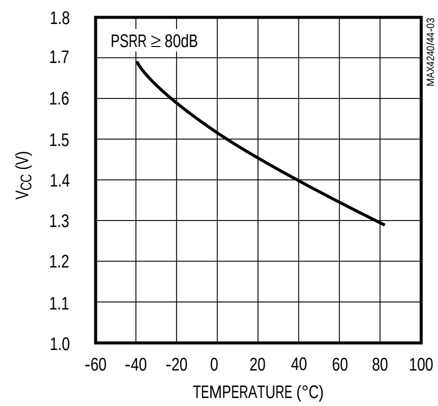
SUPPLY CURRENT PER AMPLIFIER vs. TEMPERATURE



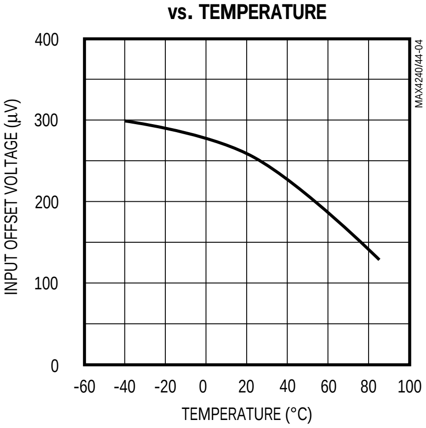
SHUTDOWN SUPPLY CURRENT PER AMPLIFIER vs. TEMPERATURE



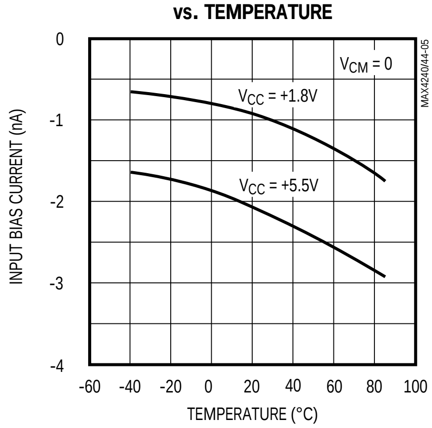
MINIMUM OPERATING VOLTAGE vs. TEMPERATURE



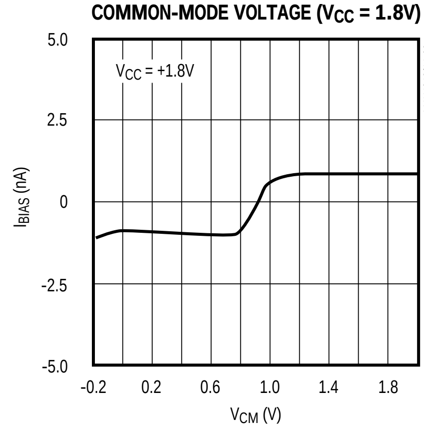
INPUT OFFSET VOLTAGE vs. TEMPERATURE



INPUT BIAS CURRENT vs. TEMPERATURE



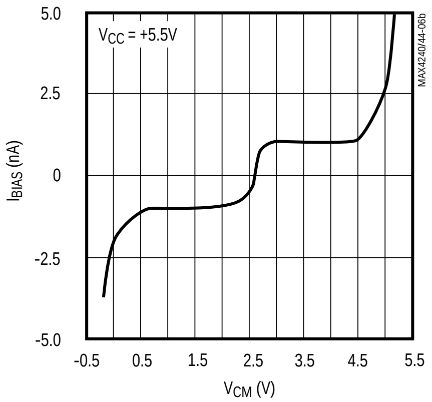
INPUT BIAS CURRENT vs. COMMON-MODE VOLTAGE (V_{CC} = 1.8V)



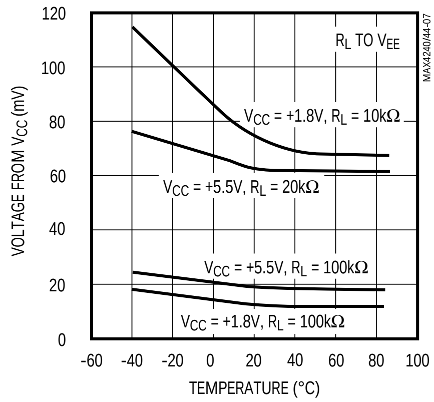
Typical Operating Characteristics (continued)

(V_{CC} = +5.0V, V_{EE} = 0, V_{CM} = V_{CC} / 2, $V_{\overline{SHDN}}$ = V_{CC}, R_L = 100kΩ to V_{CC} / 2, T_A = +25°C, unless otherwise noted.)

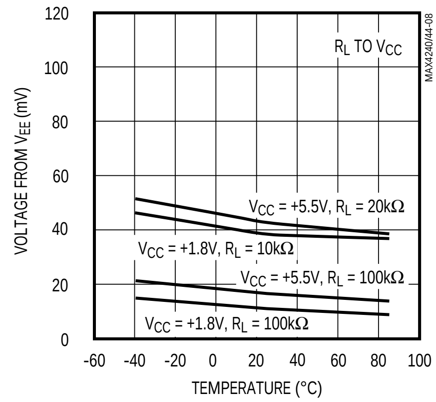
INPUT BIAS CURRENT vs. COMMON-MODE VOLTAGE (V_{CC} = 5.5V)



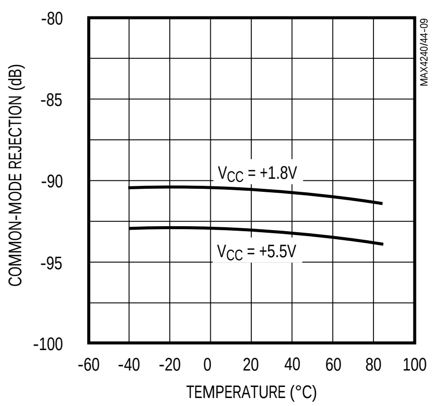
OUTPUT SWING HIGH vs. TEMPERATURE



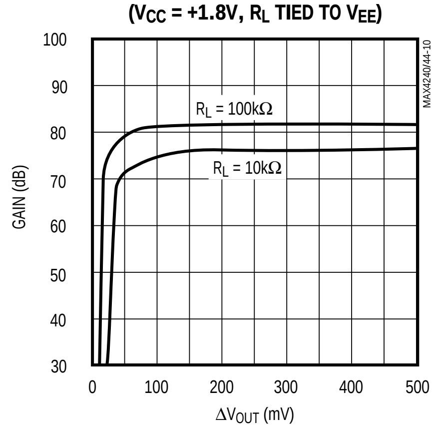
OUTPUT SWING LOW vs. TEMPERATURE



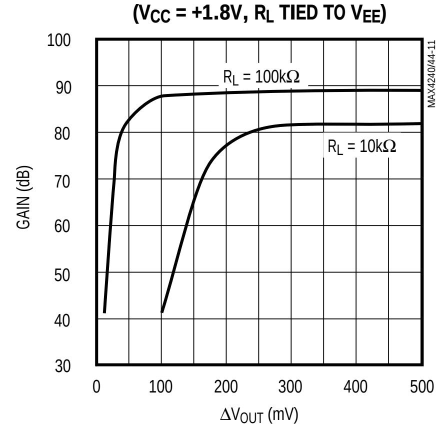
COMMON-MODE REJECTION vs. TEMPERATURE



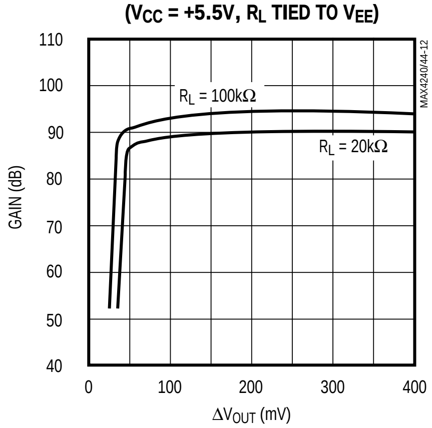
OPEN-LOOP GAIN vs. OUTPUT SWING LOW (V_{CC} = +1.8V, R_L TIED TO V_{EE})



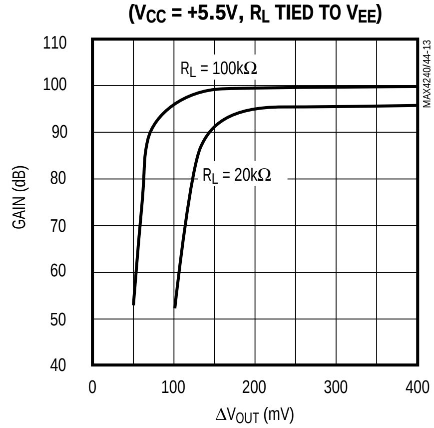
OPEN-LOOP GAIN vs. OUTPUT SWING HIGH (V_{CC} = +1.8V, R_L TIED TO V_{EE})



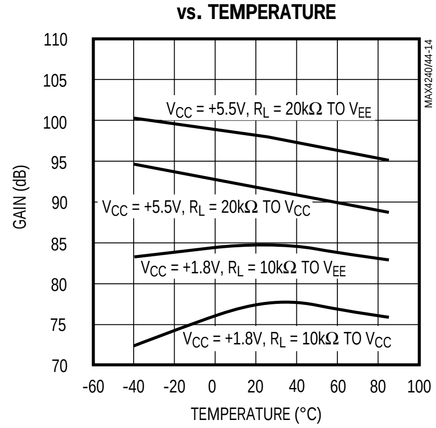
OPEN-LOOP GAIN vs. OUTPUT SWING LOW (V_{CC} = +5.5V, R_L TIED TO V_{EE})



OPEN-LOOP GAIN vs. OUTPUT SWING HIGH (V_{CC} = +5.5V, R_L TIED TO V_{EE})



OPEN-LOOP GAIN vs. TEMPERATURE

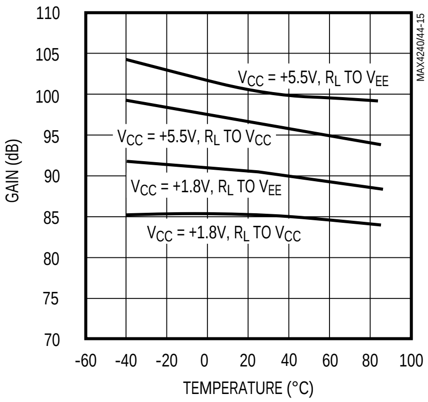


Single/Dual/Quad, +1.8V/10µA, SOT23, Beyond-the-Rails Op Amps

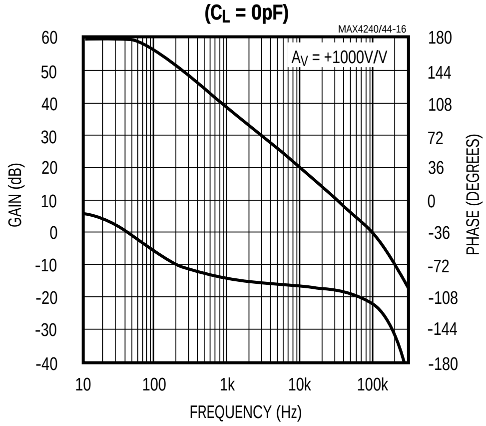
Typical Operating Characteristics (continued)

(V_{CC} = +5.0V, V_{EE} = 0, V_{CM} = V_{CC} / 2, $V_{\overline{SHDN}}$ = V_{CC}, R_L = 100kΩ to V_{CC} / 2, T_A = +25°C, unless otherwise noted.)

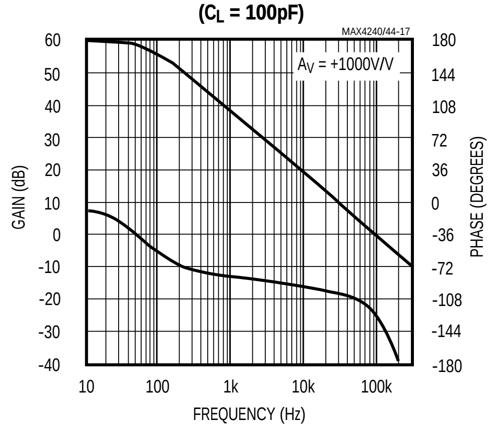
OPEN-LOOP GAIN vs. TEMPERATURE



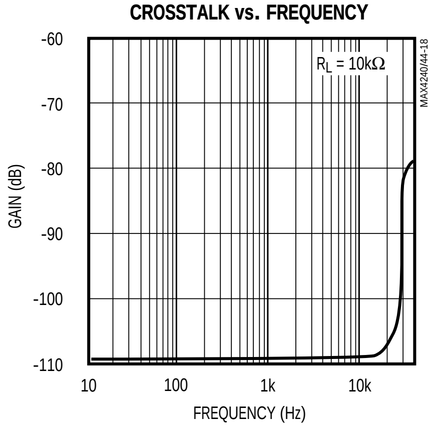
GAIN AND PHASE vs. FREQUENCY (C_L = 0pF)



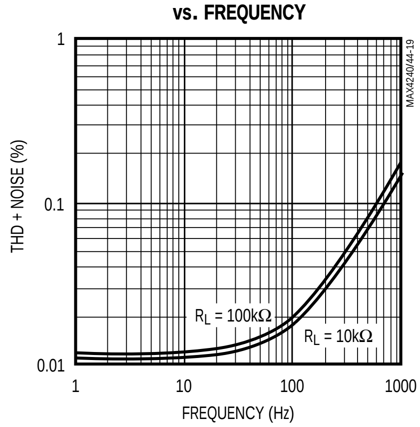
GAIN AND PHASE vs. FREQUENCY (C_L = 100pF)



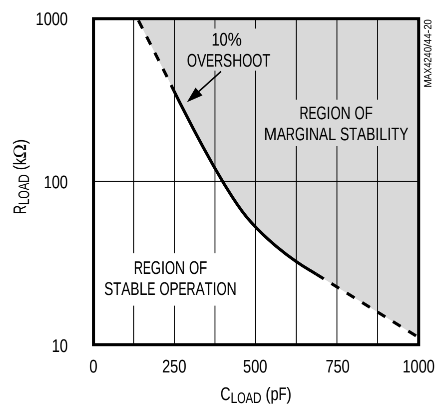
MAX4242/MAX4243/MAX4244 CROSSTALK vs. FREQUENCY



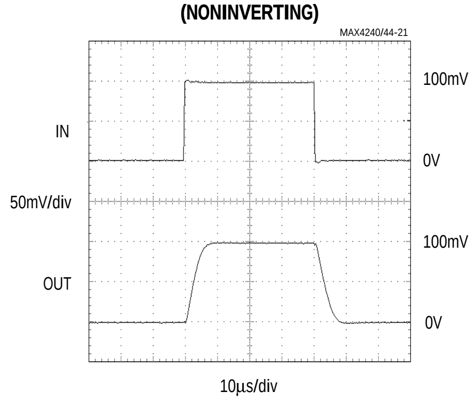
TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY



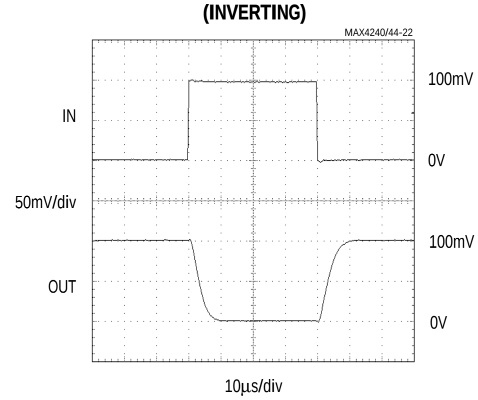
LOAD RESISTOR vs. CAPACITIVE LOAD



SMALL-SIGNAL TRANSIENT RESPONSE (NONINVERTING)



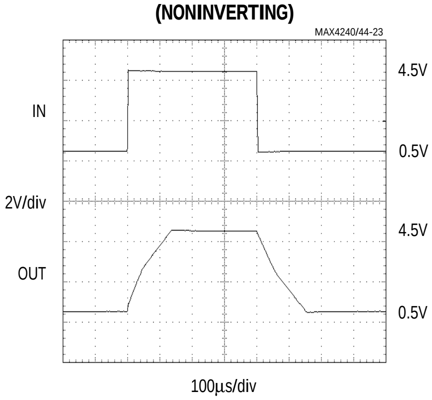
SMALL-SIGNAL TRANSIENT RESPONSE (INVERTING)



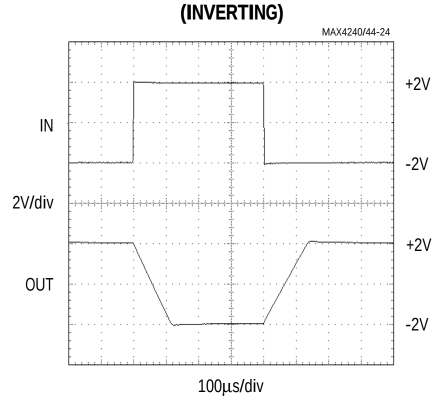
Typical Operating Characteristics (continued)

(V_{CC} = +5.0V, V_{EE} = 0, V_{CM} = V_{CC} / 2, $V_{\overline{SHDN}}$ = V_{CC}, R_L = 100kΩ to V_{CC} / 2, T_A = +25°C, unless otherwise noted.)

LARGE-SIGNAL TRANSIENT RESPONSE (NONINVERTING)



LARGE-SIGNAL TRANSIENT RESPONSE (INVERTING)



Pin Description

PIN						NAME	FUNCTION
MAX4240	MAX4241	MAX4242	MAX4243 µMAX	MAX4243 SO	MAX4244		
1	6	—	—	—	—	OUT	Amplifier Output. High impedance when in shutdown mode.
2	4	4	4	4	11	V_{EE}	Negative Supply. Tie to ground for single-supply operation.
3	3	—	—	—	—	IN+	Noninverting Input
4	2	—	—	—	—	IN-	Inverting Input
5	7	8	10	14	4	V_{CC}	Positive Supply
—	1, 5	—	—	5, 7, 8, 10	—	N.C.	No Connection. Not internally connected.
—	8	—	—	—	—	$\overline{SHDN}$	Shutdown Input. Drive high, or tie to V_{CC} for normal operation. Drive to V_{EE} to place device in shutdown mode.
—	—	1, 7	1, 9	1, 13	1, 7	OUTA, OUTB	Outputs for Amplifiers A and B. High impedance when in shutdown mode.
—	—	2, 6	2, 8	2, 12	2, 6	INA-, INB-	Inverting Inputs to Amplifiers A and B
—	—	3, 5	3, 7	3, 11	3, 5	INA+, INB+	Noninverting Inputs to Amplifiers A and B
—	—	—	5, 6	6, 9	—	$\overline{SHDNA}$, $\overline{SHDNB}$	Shutdown Inputs for Amplifiers A and B. Drive high, or tie to V_{CC} for normal operation. Drive to V_{EE} to place device in shutdown mode.
—	—	—	—	—	8, 14	OUTC, OUTD	Outputs for Amplifiers C and D
—	—	—	—	—	9, 13	INC-, IND-	Inverting Inputs to Amplifiers C and D
—	—	—	—	—	10, 12	INC+, IND+	Noninverting Inputs to Amplifiers C and D

Detailed Description

Beyond-the-Rails Input Stage

The MAX4240–MAX4244 have Beyond-the-Rails™ inputs and Rail-to-Rail® output stages that are specifically designed for low-voltage, single-supply operation. The input stage consists of separate NPN and PNP differential stages, which operate together to provide a common-mode range extending to 200mV beyond both supply rails. The crossover region of these two pairs occurs halfway between V_{CC} and V_{EE}. The input offset voltage is typically 200µV. Low operating supply voltage, low supply current, beyond-the-rails common-mode input range, and rail-to-rail outputs make this family of operational amplifiers an excellent choice for precision or general-purpose, low-voltage battery-powered systems.

Since the input stage consists of NPN and PNP pairs, the input bias current changes polarity as the common-mode voltage passes through the crossover region. Match the effective impedance seen by each input to reduce the offset error caused by input bias currents flowing through external source impedances (Figures 1a and 1b). The combination of high source impedance plus input capacitance (amplifier input capacitance plus stray capacitance) creates a parasitic pole that produces an underdamped signal response. Reducing input capacitance or placing a small capacitor across the feedback resistor improves response in this case.

The MAX4240–MAX4244 family's inputs are protected from large differential input voltages by internal 2.2kΩ series resistors and back-to-back triple-diode stacks across the inputs (Figure 2). For differential input voltages (much less than 1.8V), input resistance is typically 45MΩ. For differential input voltages greater than 1.8V, input resistance is around 4.4kΩ, and the input bias current can be approximated by the following equation:

$$I_{BIAS} = (V_{DIFF} - 1.8V) / 4.4k\Omega$$

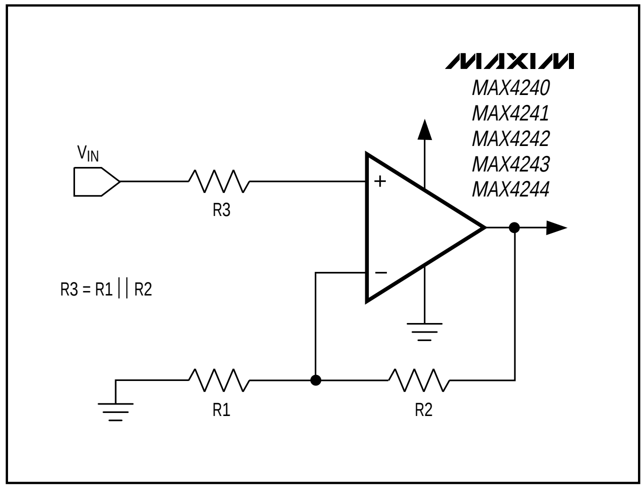


Figure 1a. Minimizing Offset Error Due to Input Bias Current (Noninverting)

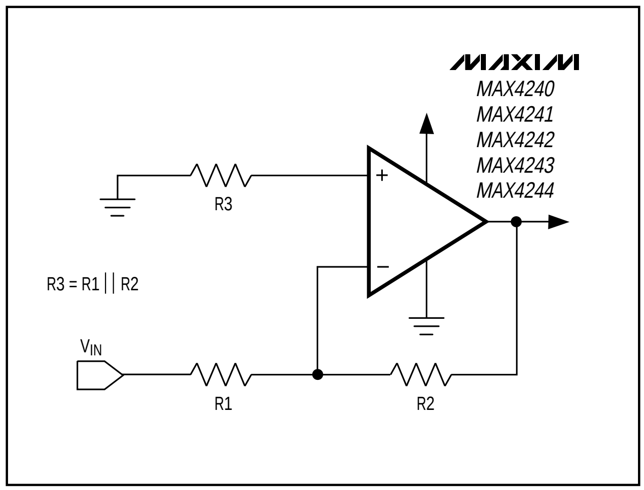


Figure 1b. Minimizing Offset Error Due to Input Bias Current (Inverting)

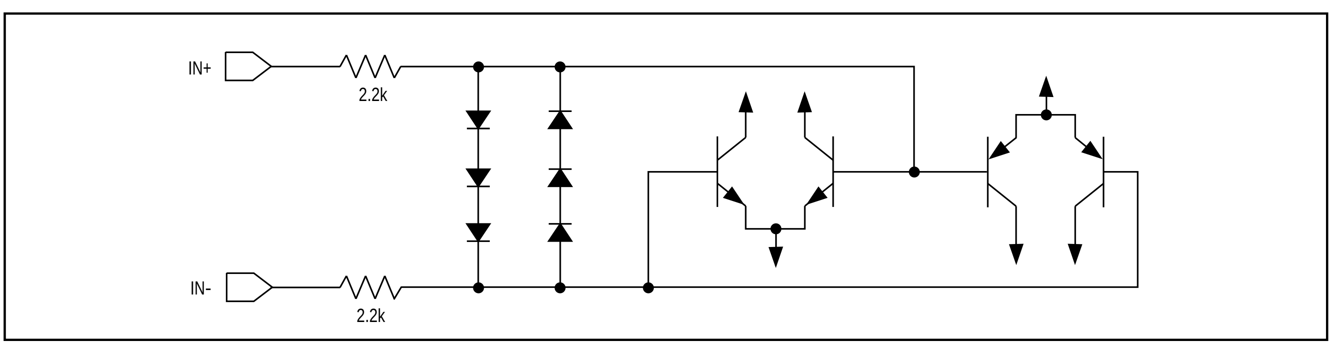


Figure 2. Input Protection Circuit

In the region where the differential input voltage approaches 1.8V, the input resistance decreases exponentially from 45MΩ to 4.4kΩ as the diode block begins conducting. Conversely, the bias current increases with the same curve.

Rail-to-Rail Output Stage

The MAX4240–MAX4244 output stage can drive up to a 10kΩ load and still swing to within 40mV of the rails. Figure 3 shows the output voltage swing of a MAX4240 configured as a unity-gain buffer, powered from a single +2V supply voltage. The output for this setup typically swings from (V_{EE} + 6mV) to (V_{CC} - 8mV) with a 100kΩ load.

Applications Information

Power-Supply Considerations

The MAX4240–MAX4244 operate from a single +1.8V to +5.5V supply (or dual ±0.9V to ±2.75V supplies) and consume only 10µA of supply current per amplifier. A high power-supply rejection ratio of 90dB allows the amplifiers to be powered directly off a decaying battery voltage, simplifying design and extending battery life.

The MAX4240–MAX4244 are ideally suited for use with most battery-powered systems. Table 1 lists a variety of typical battery types showing voltage when fresh, voltage at end-of-life, capacity, and approximate operating time from a MAX4240/MAX4241, assuming nominal conditions for both normal and shutdown modes.

Although the amplifiers are fully guaranteed over temperature for operation down to a +1.8V single supply, even lower-voltage operation is possible in practice. Figures 4 and 5 show the PSRR and supply current as a function of supply voltage and temperature.

Power-Up Settling Time

The MAX4240–MAX4244 typically require 200µs to power up after V_{CC} is stable. During this start-up time, the output is indeterminant. The application circuit should allow for this initial delay.

Shutdown Mode

The MAX4241 (single) and MAX4243 (dual) feature a low-power shutdown mode. When the shutdown pin ($\overline{SHDN}$) is pulled low, the supply current drops to 1µA per amplifier, the amplifier is disabled, and the outputs enter a high-impedance state. Pulling $\overline{SHDN}$ high or leaving it floating enables the amplifier. Take care to ensure that parasitic leakage current at the $\overline{SHDN}$ pin does not inadvertently place the part into shutdown mode when $\overline{SHDN}$ is left floating. Figure 6 shows the output voltage response to a shutdown pulse. The logic threshold for $\overline{SHDN}$ is always referred to V_{CC} / 2 (not to

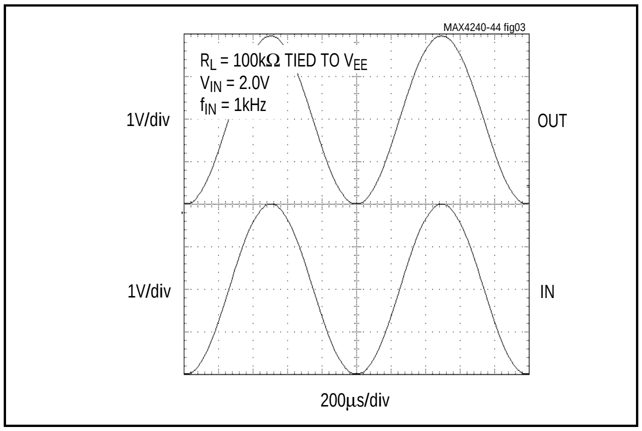


Figure 3. Rail-to-Rail Input/Output Voltage Range

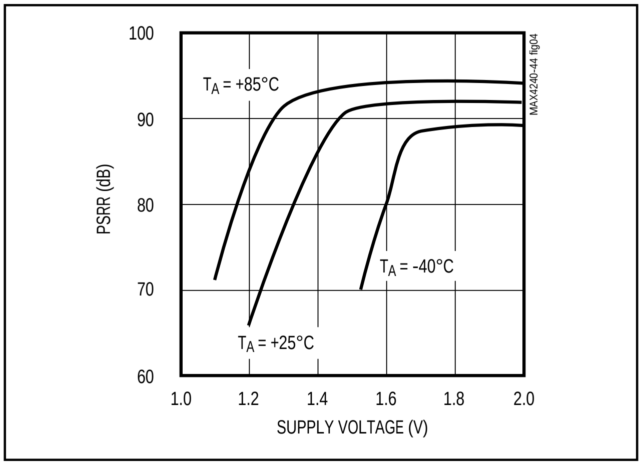


Figure 4. Power-Supply Rejection Ratio vs. Supply Voltage

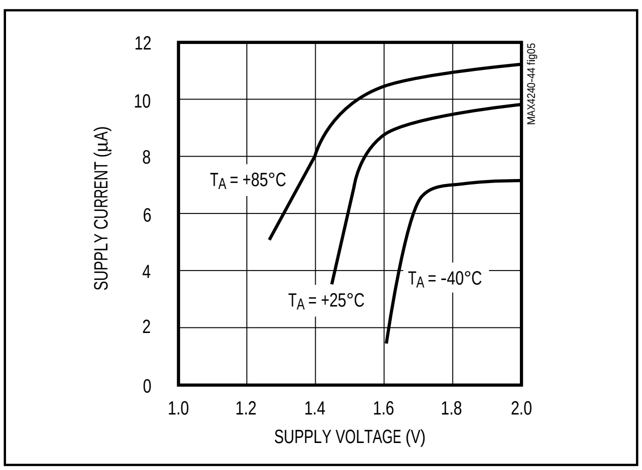


Figure 5. Supply Current vs. Supply Voltage

Table 1. MAX4240/MAX4241 Characteristics with Typical Battery Systems

BATTERY TYPE	RECHARGEABLE	V_{FRESH} (V)	$V_{END-OF-LIFE}$ (V)	CAPACITY, AA SIZE (mA-h)	MAX4240/MAX4241 OPERATING TIME IN NORMAL MODE (Hours)	MAX4241 OPERATING TIME IN SHUTDOWN MODE (Hours)
Alkaline (2 Cells)	No	3.0	1.8	2000	200,000	2×10^6
Nickel-Cadmium (2 Cells)	Yes	2.4	1.8	750	75,000	0.75×10^6
Lithium-Ion (1 Cell)	Yes	3.5	2.7	1000	100,000	10^6
Nickel-Metal-Hydride (2 Cells)	Yes	2.4	1.8	1000	100,000	10^6

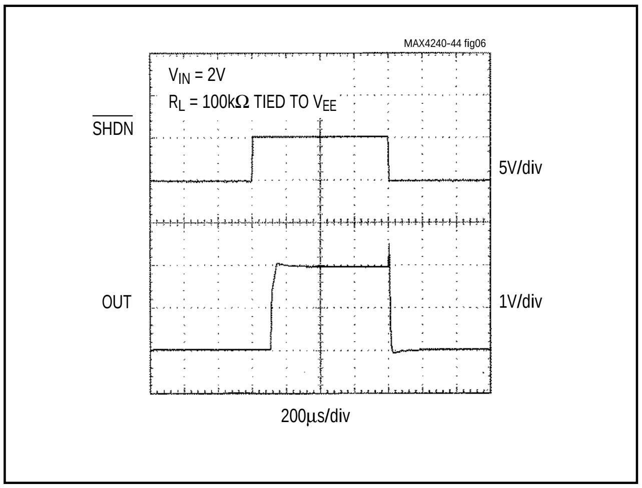


Figure 6. Shutdown Enable/Disable Output Voltage

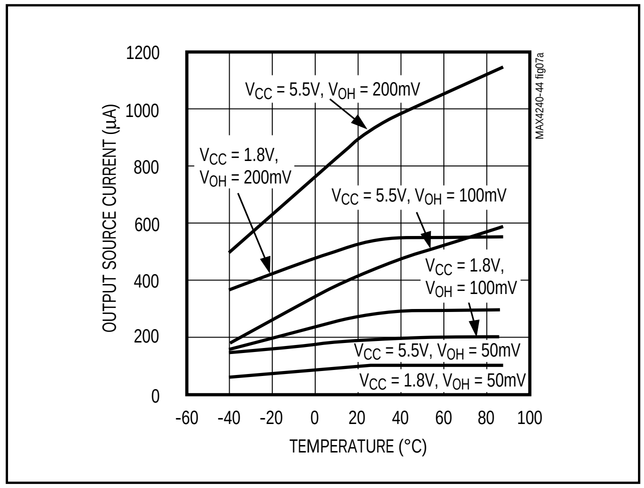


Figure 7a. Output Source Current vs. Temperature

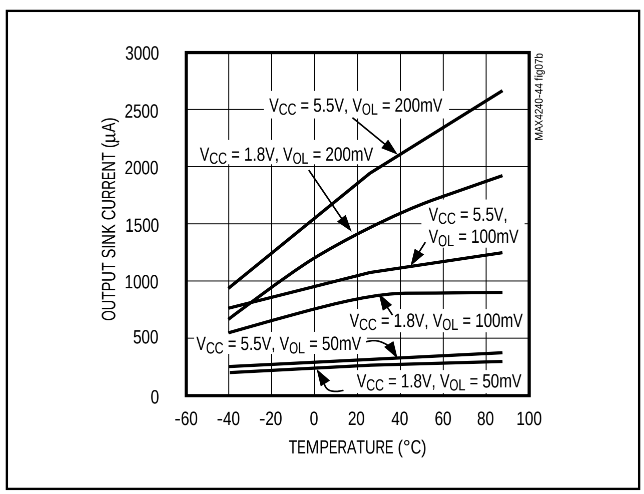


Figure 7b. Output Sink Current vs. Temperature

GND). When using dual supplies, pull $\overline{SHDN}$ to V_{EE} to enter shutdown mode.

Load-Driving Capability

The MAX4240–MAX4244 are fully guaranteed over temperature and supply voltage to drive a maximum resistive load of 10kΩ to V_{CC} / 2, although heavier loads can be driven in many applications. The rail-to-rail output stage of the amplifier can be modeled as a current source when driving the load toward V_{CC}, and as a current sink when driving the load toward V_{EE}. The magnitude of this current source/sink varies with supply voltage, ambient temperature, and lot-to-lot variations of the units.

Figures 7a and 7b show the typical current source and sink capability of the MAX4240–MAX4244 family as a function of supply voltage and ambient temperature. The contours on the graph depict the output current value, based on driving the output voltage to within 50mV, 100mV, and 200mV of either power-supply rail.

For example, a MAX4241 running from a single +1.8V supply, operating at T_A = +25°C, can source 240µA to within 100mV of V_{CC} and is capable of driving a 7kΩ load resistor to V_{EE}:

$$R_L = \frac{1.8V - 0.1V}{240\mu A} = 7k\Omega \text{ to } V_{EE}$$

The same application can drive a 3.3kΩ load resistor when terminated in V_{CC} / 2 (+0.9V in this case).

Driving Capacitive Loads

The MAX4240–MAX4244 are unity-gain stable for loads up to 200pF (see Load Resistor vs. Capacitive Load graph in *Typical Operating Characteristics*). Applications that require greater capacitive drive capability should use an isolation resistor between the output and the capacitive load (Figure 8). Note that this alternative results in a loss of gain accuracy because R_{ISO} forms a voltage divider with the load resistor.

Power-Supply Bypassing and Layout

The MAX4240–MAX4244 family operates from either a single +1.8V to +5.5V supply or dual ±0.9V to ±2.75V supplies. For single-supply operation, bypass the power supply with a 100nF capacitor to V_{EE} (in this case GND). For dual-supply operation, both the V_{CC} and V_{EE} supplies should be bypassed to ground with separate 100nF capacitors.

Good PC board layout techniques optimize performance by decreasing the amount of stray capacitance at the op amp's inputs and output. To decrease stray capacitance, minimize trace lengths by placing external components as close as possible to the op amp. Surface-mount components are an excellent choice.

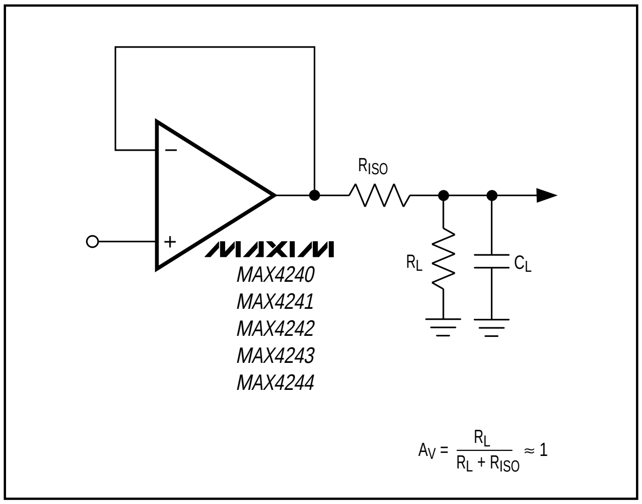


Figure 8a Using a Resistor to Isolate a Capacitive Load from the Op Amp

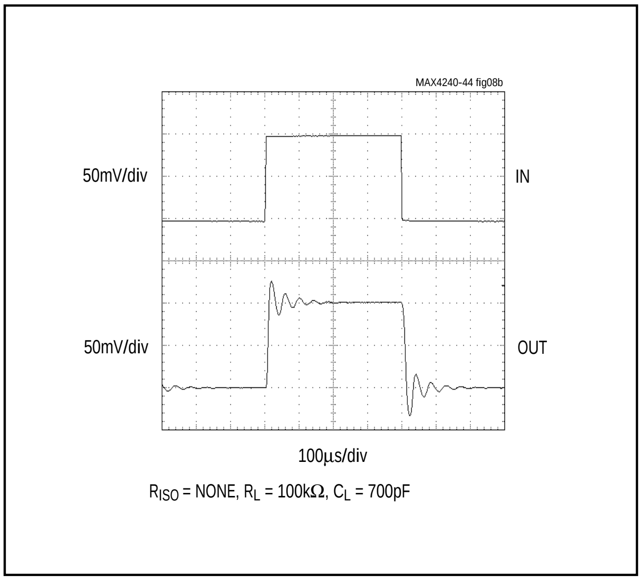


Figure 8b. Pulse Response without Isolating Resistor

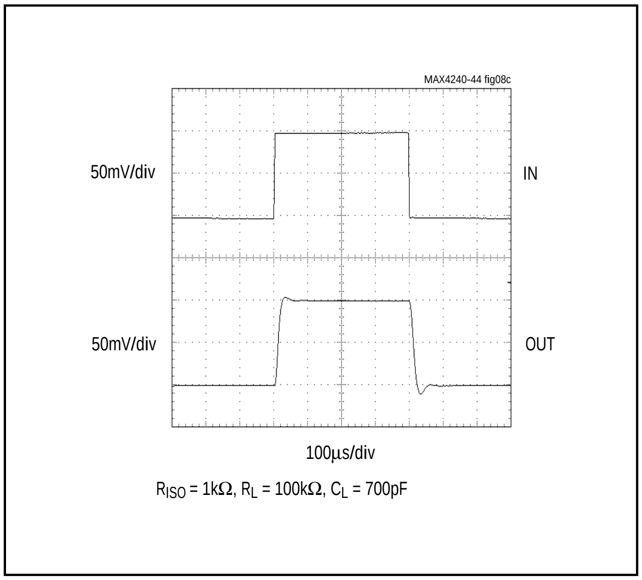


Figure 8c. Pulse Response with Isolating Resistor

Using the MAX4240–MAX4244 as Comparators

Although optimized for use as operational amplifiers, the MAX4240–MAX4244 can also be used as rail-to-rail I/O comparators. Typical propagation delay depends on the input overdrive voltage, as shown in Figure 9. External hysteresis can be used to minimize the risk of output oscillation. The positive feedback circuit, shown in Figure 10, causes the input threshold to change when the output voltage changes state. The two thresholds create a hysteresis band that can be calculated by the following equations:

$$V_{HYST} = V_{HI} - V_{LO}$$

$$V_{LO} = V_{IN} \times R2 / (R1 + (R1 \times R2 / R_{HYST}) + R2)$$

$$V_{HI} = [(R2 / R1 \times V_{IN}) + (R2 / R_{HYST}) \times V_{CC}] / (1 + R1 / R2 + R2 / R_{HYST})$$

The MAX4240–MAX4244 contain special circuitry to boost internal drive currents to the amplifier output stage. This maximizes the output voltage range over which the amplifiers are linear. In an open-loop comparator application, the excursion of the output voltage is so close to the supply rails that the output stage transistors will saturate, causing the quiescent current to increase from the normal 10µA. Typical quiescent currents increase to 35µA for the output saturating at V_{CC} and 28µA for the output at V_{EE}.

Using the MAX4240–MAX4244 as Ultra-Low-Power Current Monitors

The MAX4240–MAX4244 are ideal for applications powered from a 2-cell battery stack. Figure 11 shows an application circuit in which the MAX4240 is used for monitoring the current of a 2-cell battery stack. In this circuit, a current load is applied, and the voltage drop at the battery terminal is sensed.

The voltage on the load side of the battery stack is equal to the voltage at the emitter of Q1, due to the feedback loop containing the op amp. As the load current increases, the voltage drop across R1 and R2 increases. Thus, R2 provides a fraction of the load current (set by the ratio of R1 and R2) that flows into the emitter of the PNP transistor. Neglecting PNP base current, this current flows into R3, producing a ground-referenced voltage proportional to the load current. Scale R1 to give a voltage drop large enough in comparison to V_{OS} of the op amp, in order to minimize errors.

The output voltage of the application can be calculated using the following equation:

$$V_{OUT} = [I_{LOAD} \times (R1 / R2)] \times R3$$

For a 1V output and a current load of 50mA, the choice of resistors can be R1 = 2Ω, R2 = 100kΩ, R3 = 1MΩ. The circuit consumes less power (but is more susceptible to noise) with higher values of R1, R2, and R3.

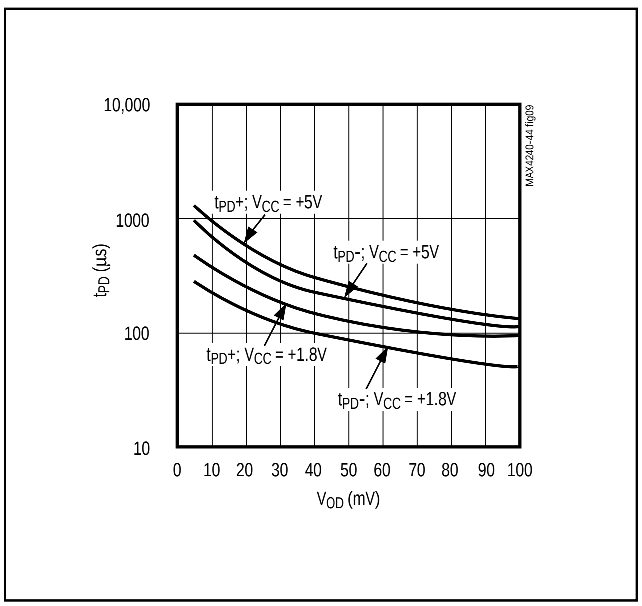


Figure 9. Propagation Delay vs. Input Overdrive

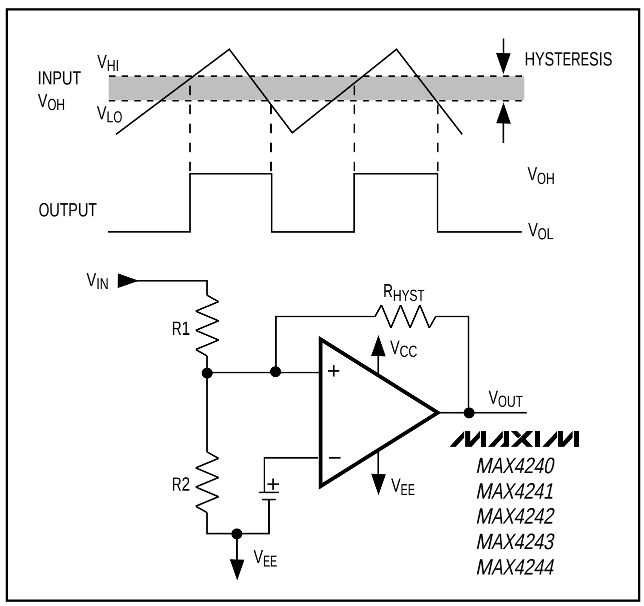


Figure 10. Hysteresis Comparator Circuit

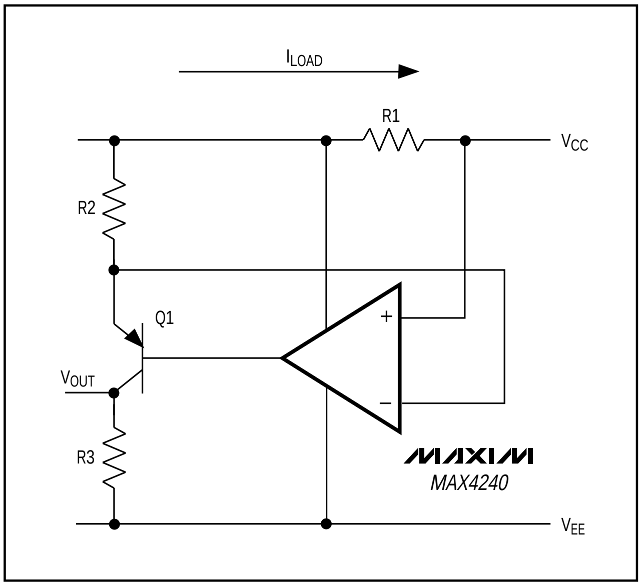


Figure 11. Current Monitor for a 2-Cell Battery Stack

Chip Information

MAX4240/MAX4241

TRANSISTOR COUNT: 234

MAX4242/MAX4243

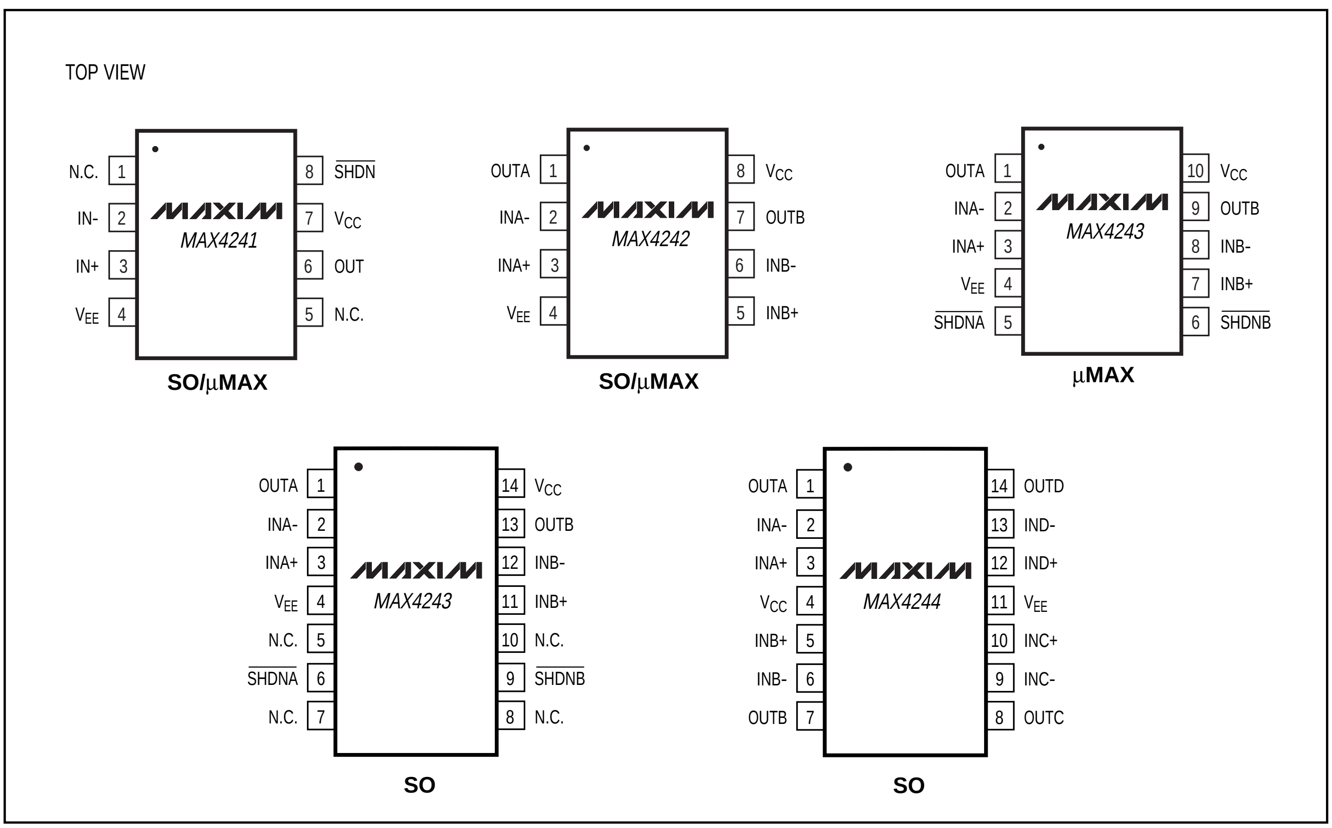
TRANSISTOR COUNT: 466

MAX4244

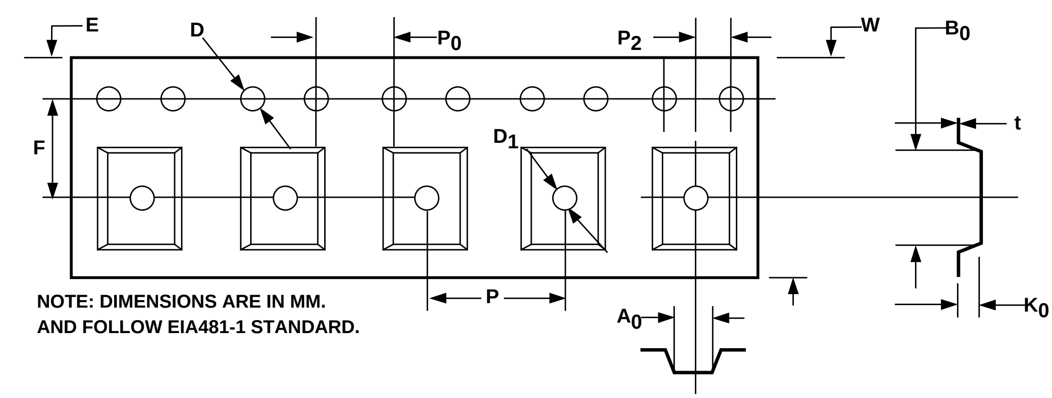
TRANSISTOR COUNT: 932

SUBSTRATE CONNECTED TO V_{EE}

Pin Configurations (continued)



Tape-and-Reel Information



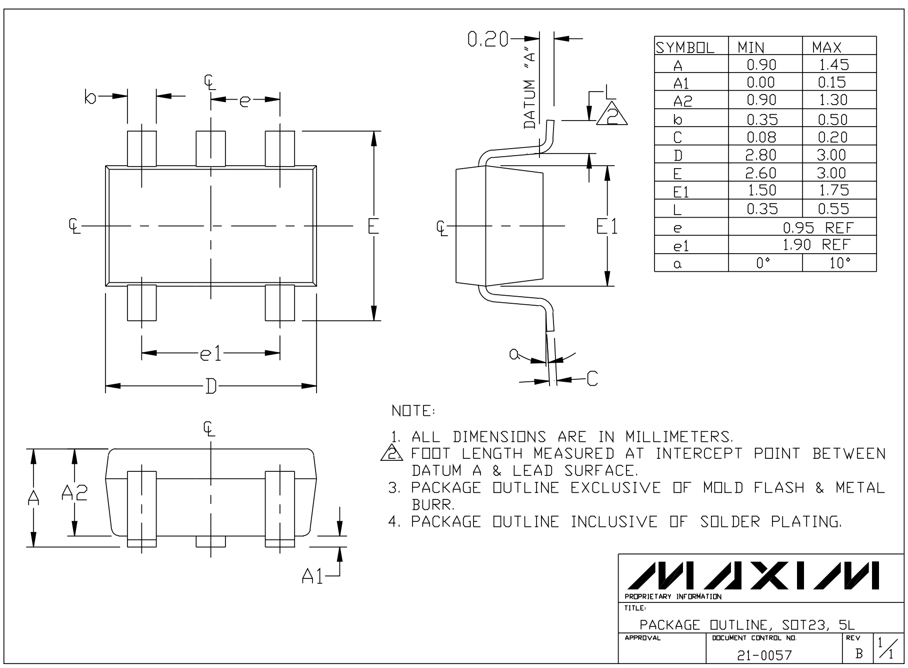
A_0	3.200	±0.102
B_0	3.099	±0.102
D	1.499	+0.102 +0.000
D_1	0.991	+0.254 +0.000

E	1.753	±0.102
F	3.505	±0.051
K_0	1.397	±0.102
P	3.988	±0.102

P_0	3.988	±0.102
P_010	40.005	±0.203
P_2	2.007	±0.051
t	0.254	±0.127
W	8.001	+0.305 -0.102

5 SOT23-5

Package Information



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	
α	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. 21-0057 | REV B | 1/1